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Astronautics

A PUBLICATION OF THE AMERICAN ROCKET SOCIETY

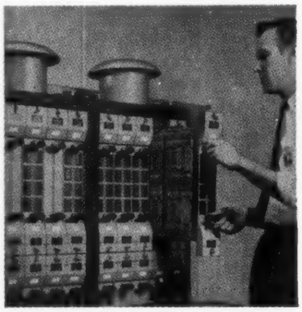
NOVEMBER 1960

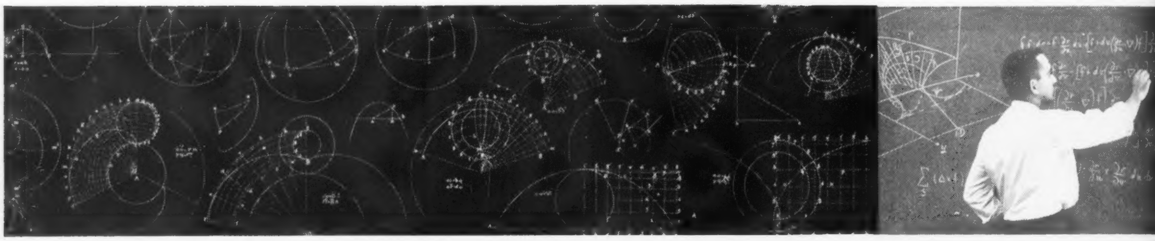
THIRD ASTRONAUTICS ANNUAL

ARS 15th ANNUAL MEETING AND EXPOSITION PREVIEW

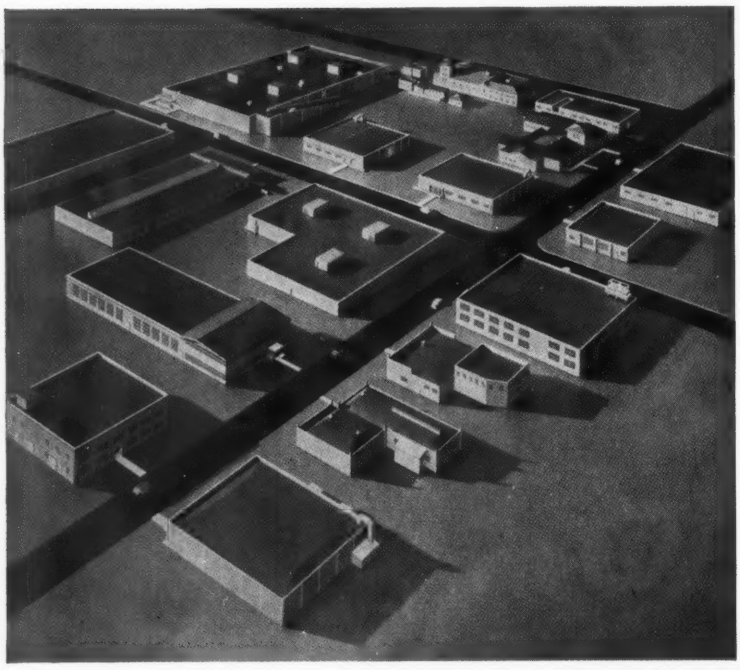
LIBRASCOPE COMPUTER FACILITIES

Shown below is a composite view of Librascope's facilities where a variety of computer systems are currently in different stages of design and production. Some are strategically involved with national defense...others deal with business and industrial process control. Each is uniquely designed to answer a particular need. The success of these systems illustrates the value of Librascope's engineering philosophy: A decentralized organization of specialized project teams responsible for assignments from concept to delivery...and backed up by excellent research, service, and production facilities. For your computer requirements, call on the company whose breadth of diversification in computer technology is unsurpassed. ■ Librascope Division, General Precision, Inc., 808 Western Avenue, Glendale, Calif. For career opportunities write to John Schmidt, Engineering Employment. ■





computers that pace man's expanding mind



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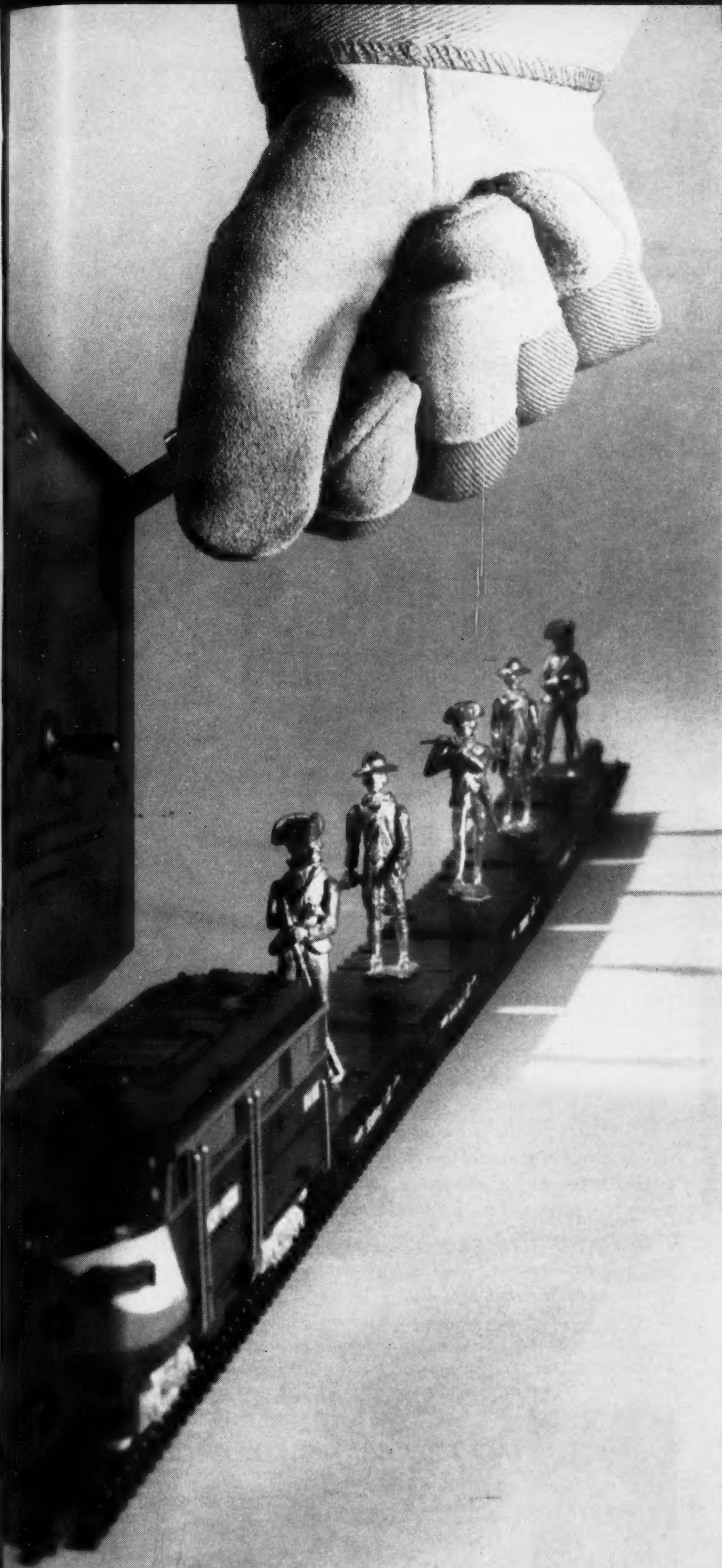

He's got Minutemen "working on the railroad"

Hard basing is one way to protect America's force of retaliatory ICBM's. The problem was to find an alternate means of accomplishing the same mission. The Air Force solution was a new ICBM mobility concept—railroad car-mounted Minutemen, utilizing the nation's vast track mileage for numerical and geographical dispersion, creating a difficult target for enemy attack.

To put the Minuteman, its support systems and associated equipment on rails was a completely new problem in missile handling. The first requirement assigned by Boeing to American Machine & Foundry Company and ACF Industries, Inc., was a feasibility study of the existing limitations of roadbeds, rails, railroad operations and right-of-way. Unique tactical cars are being designed within these limitations to carry the Minuteman—cars that can handle the missile and its operating equipment, safely isolated from roadbed shock and ready for immediate retaliatory launching.

Single Command Concept

Whether for conceptual problems such as this one, or for challenges in design or manufacturing, AMF has ingenuity you can use. AMF people are organized in a single operational unit offering a wide range of engineering and production capability. Its purpose—to accept assignments at any stage from concept through development, to production, and service training...and to complete them faster in

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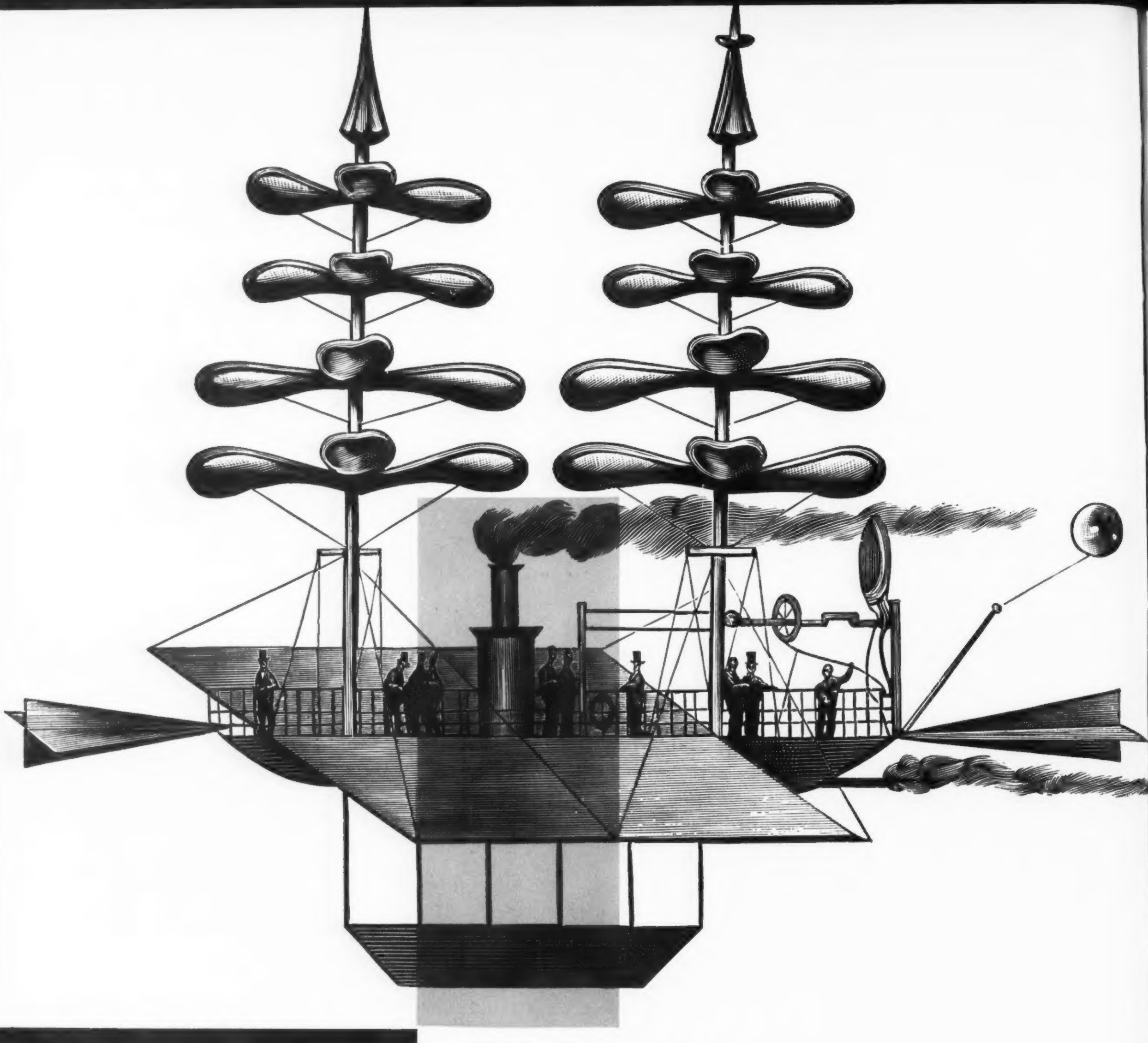
engineering and manufacturing AMF has ingenuity you can use... **AMERICAN MACHINE & FOUNDRY COMPANY**



The basic principle of the helicopter was first advanced in 1863 by Gabriel De La Landelle of France. Rising steam was expected to turn the air screws and lift the craft upward. For this illustration, Brussel-Smith has followed earlier renderings of the "Steam Airliner" to create this intricate wood engraving.

IMAGINATION IN SPACE

Since Creation, man has looked out on space. At first, unknowing and incurious; then with the beginnings of understanding; now free and able t explore. Yet to move in space calls for wholly new concepts of energy.

This, then, is the working philosophy of Hercules in chemical propulsio To design and manufacture highly concentrated packages of energy as propellants and rocket motors; each compatible, controllable, predictable; and each perfected for its specific mission.

HERCULES' BACKGROUND: A half-century of creative imagination in the evolution of propellants, from shotgun powder to the manufacture of the propellants for all the U. S. rockets fired during World War II, and now to space propulsion. Hercules facilities today encompass research, design, engineering, and staff organization for the production of the most advanced propellants. Illustrated brochur available on request.

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Astronautics

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EDITORIAL

FEATURES

STATE OF THE ART, 1960

ANNUAL MEETING

DEPARTMENTS

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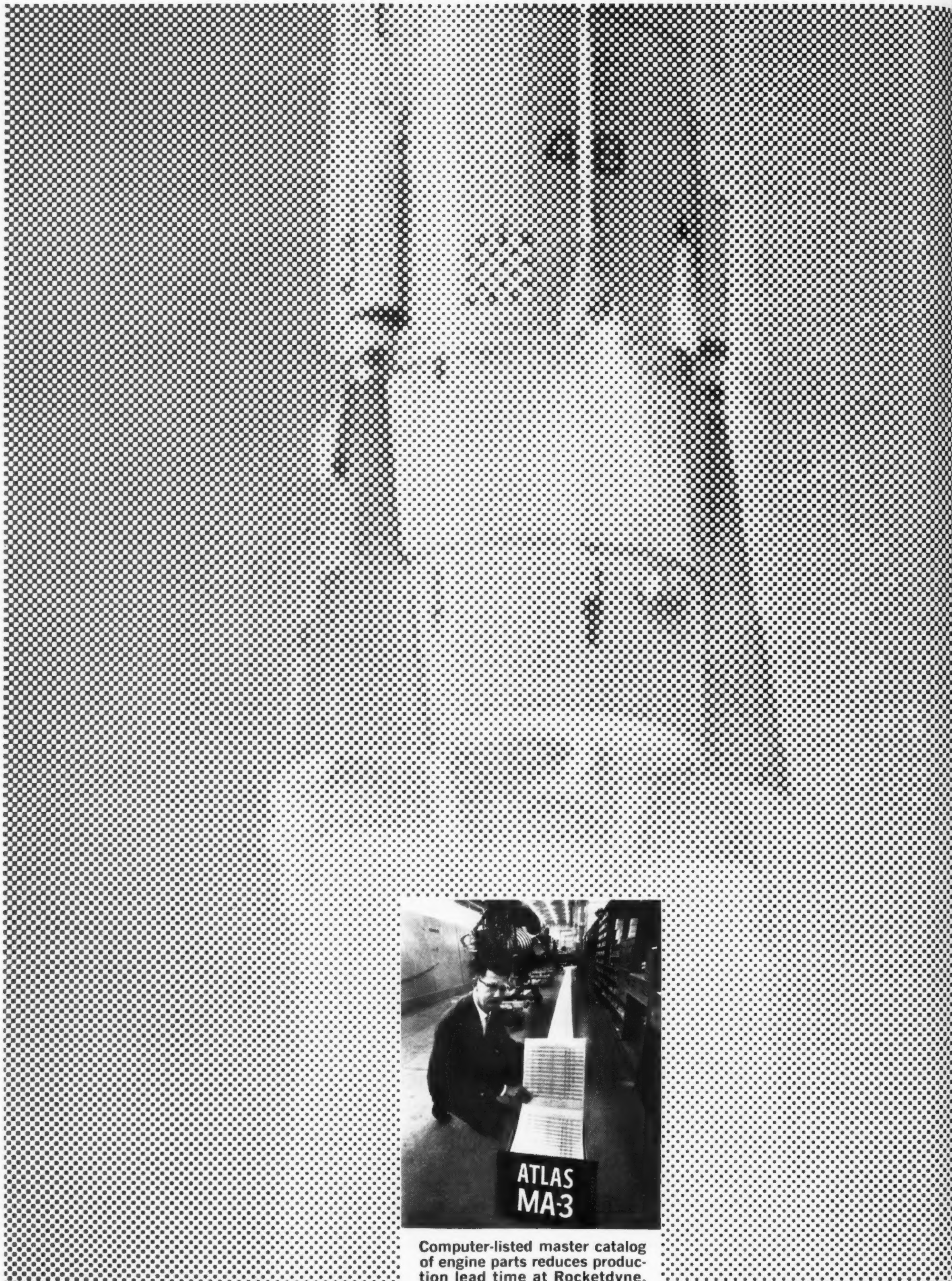
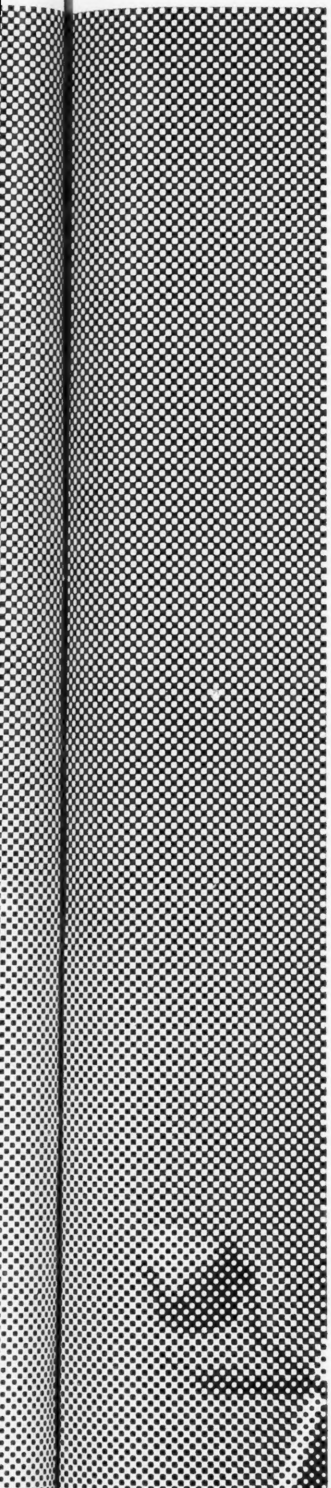


Computer-listed master catalog of engine parts reduces production lead time at Rocketdyne.



Keeping the cost of space down to earth

Behind the thundering performance of Rocketdyne's engines, a significant reduction in the cost of power for America's missiles has been quietly achieved. Today, Rocketdyne engineering skill and efficient production methods make it possible to power two missiles for the cost of one in 1957.

Rocketdyne, the pioneer in rocket science, was first with power for America's long range ballistic missiles—first with power for outer space. In establishing this technological leadership, Rocketdyne developed new management concepts at every level of operation, from early design through final testing. The result is outstanding technical achievement at the lowest possible cost.

In data processing alone, advanced techniques are saving engineers hundreds of hours of experimentation and testing and have contributed to a 37 percent reduction in Atlas engine costs for the Air Force. An intracompany communications network links test stands and research laboratories in Missouri, Texas and California; gives management the daily status of every program—whether it's on schedule, what parts are in short supply, how the production line is performing.

Through research, engineering, and management, Rocketdyne is constantly at work not only to increase thrust performance and develop new propulsion techniques, but at the same time to reduce costs all along the line.

25 of America's 28 successful satellites and space probes have been launched by Rocketdyne engines.

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DIVISION OF NORTH AMERICAN AVIATION

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Astro notes

SPACE PROBES

• Watch for another NASA attempt in December to orbit the moon with a 387-lb Pioneer VI payload. The September moon shot failed when the Atlas-Able launching vehicle suffered faulty ignition and premature shutdown of its second-stage motor. Imperfect separation from the Atlas stage may have been responsible.

• NASA put its four-stage, solid-propellant Scout vehicle through a strenuous 80-min ballistic flight in which it carried a 112-lb payload to an altitude of 3500 st mi before plunging into the Atlantic 5800 mi downrange from Wallops Island. Cape Canaveral received 63 min of telemetry from the payload, which included a 78-lb package of instruments supplied by the AF Special Weapons Center. Latter consisted of a magnetometer and an array of eight radiation detectors to gather more refined measurements of the inner Van Allen radiation belt.

• AF also launched its own Scout vehicle, a 40-ft assembly dubbed Blue Scout Junior, which carried a 32.8-lb AFSWC payload to a calculated altitude of 17,000 mi in a flight of 6 hr and 20 min from Cape Canaveral. Unfortunately, telemetry failed 8 sec after fourth-stage burnout so that data from the neutron and X-ray detectors and two Geiger counters were lost. First two stages of Blue Scout Junior are the second (Castor/Sergeant) and third (Antares) stage of NASA's regular 72-ft Scout, while the third and fourth are different.

• Another successful first flight was achieved by the Argo D-8, a four-stage 62-ft rocket consisting of a Sergeant plus two Recruits, Lance rockets for 2nd and 3rd stages, and an X-248 rocket. The spin-stabilized vehicle carried NASA's Nerv experiment to a 1200-mi altitude, after which it was recovered by a Navy destroyer. Heart of the 83.6-lb package was a half-inch stack of film emulsions to measure 5 mev charged particles. Also included were micrometeorite and mold spore experiments.

MISSILES

• AF has selected Griffiss AFB, Rome, N.Y., as the support base for its last two Titan squadrons. The 18 underground silos will cost $80 million to construct and will require 1200 men to operate. Each site will be fully dispersed and hardened to several hundred psi, and will house a 110-ft Titan II missile with storable propellants aboard. The Titan program provides for a total of 14 squadrons, including 6 Titan I and 8 Titan II squadrons.

• Continuing its campaign to advertise the feasibility of the Nike-Zeus anti-ICBM concept, the Army succeeded in knocking down a Nike-Hercules missile with another Nike-Hercules. The intercept occurred at a 19-mi altitude at a combined velocity of Mach 7—the most spectacular demonstration yet of the pinpoint guidance capabilities of the Nike system. The Army also gave Nike-Zeus some more direct support funds by awarding Western Electric, the prime contractor, a $199,125,000 contract to carry R&D work forward another year.

• Sylvania has received a $7.5 million subcontract from Boeing to develop special underground radio communication facilities for command and control of individual Minuteman ICBM's. More secure than the buried cable network originally planned, the Sylvania system will include message processing devices, signal transmitting and receiving equipment, and buried antennas.

• AF has mapped a $370 million program for development of the GAM-87 Skybolt air-launched ballistic missile, including obligations of $150 million this fiscal year and $110 million in fiscal 1962. The airmen are confident that they can have the Pershing-sized two-stage weapon operational in SAC by early 1964. A B-52 will be able to carry four 1000-mi Skybolts slung beneath its wings, compared with two 500-mi air-breathing Hound Dogs.

• Although Skybolt guidance from a moving platform would appear to be the toughest problem, it is actually quite straightforward. The regular bomb-navigation system of the B-52 will supply altitude and velocity information to the Skybolt's computer with acceptable accuracy, while the star tracker mounted over the reference table of the missile's inertial platform will provide azimuth corrections to 3 min of arc. Once the launching aircraft "zeroes" the missile over the earth's surface within 2000 ft, Skybolt can be released and fired after a short time delay.

• Probably the most difficult Skybolt problem will be the development of a motor which can withstand the severe temperature changes imposed by operation in a jet aircraft environment. The solid propellant must withstand a temperature change from 120 F on the runway to −65 F in the stratosphere within a 30-min period, and it must also withstand prolonged engine noise and vibration.

SPACE POWER SYSTEMS

• AF has ordered Hamilton Standard Div. of United Aircraft to build a prototype solar-powered thermoelectric generator of 100-watt output. It will consist of 900 aluminum reflectors 4 in. in diam which will focus the sun's heat on one end of a thermocouple in the center of each reflector. The difference in the heat potential between the hot (1000 F) and cool (400 F) end of the thermocouple will generate a voltage. Ham-Stan said its first model will be about 100 sq ft in area and added that it also is planning a 1.5-kw model using 7000 reflectors covering 70 sq ft.

• Rocketdyne has proposed a novel moving belt radiator to carry waste heat away from nuclear powerplants in space. It visualizes a pair of continuously moving belts which pick up heat from the outer surface of the nuclear core and radiate it away into space. During launch, the belts would be folded around the generator, only going into operation after the reactor was activated. Chief advantage of the belt radiator is its light weight. Rocketdyne believes an 80-ft, 800-lb belt could cool a 300-kw reactor system, compared with 1800 lb for a conventional fin-and-tube radiator system.

• GE is working on a watermelon-sized reactor-generator system capable of producing 5 to 30 kw without moving parts. Thermionic cells operating at 3100 F would form a shell surrounding the graphite wall of the reactor, carrying away its heat and generating electricity at the same time.

• Both GE and Martin Co. are working on new methods for obtaining radioactive heat sources suitable for Snap space power applications. Martin plans to purify Americium

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MARQUARDT CONSOLIDATION STRENGTHENS OVER-ALL ROCKET SYSTEMS CAPABILITIES

Cooper Development Division to Centralize Operations in Van Nuys

In the next few months the entire Cooper Development Division will move to the Van Nuys headquarters of The Marquardt Corporation. By concentrating aero/space operations in one centralized, fully equipped facility, the full capabilities of Cooper can be better focused on the technological problems facing government, industry, and private research groups.

Cooper Development Division will be in direct contact with extensive testing facilities and the combined experience and knowledge of the Power Systems Group and the ASTRO Division. Power Systems Group maintains an outstanding reputation in advanced rocket engine concepts, fuels and propellant research, high temperature materials development and experimentation, and advanced manufacturing techniques. A close working relation with the ASTRO Division will provide a nationally recognized source of basic and applied research information as it pertains to CDD's operations.

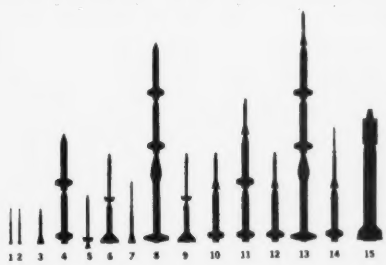
CDD, located in Monrovia, California when acquired by Marquardt in 1958, provides complete and proven high altitude rocket research services. These high altitude or space probe systems are designed for wind measurement; meteorological, radiation and biological information; and similar military and scientific high altitude aero/space programs.

CDD supplies a complete project service—from design, development, and production to field testing and data evaluation—for rocket research systems. Now with immediate access to larger testing and manufacturing facilities and directly supported by Marquardt's more than fifteen years of comprehensive experience in the propulsion field, CDD can offer their customers broader, faster problem solutions on an even more competitive cost basis.

Detailed information covering Cooper's experience, capabilities, products and services may be obtained by writing A. B. Metsger, Vice President-General Manager, Cooper Development Division, The Marquardt Corporation, 16555 Saticoy Street, Van Nuys, California.

Engineers and scientists experienced in aero/space activities are invited to acquaint themselves with the outstanding career opportunities in the field of rocketry at The Marquardt Corporation.

The Cooper Family of Rockets



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2. ROKSONDE 200
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4. PYTHON
5. ASP IV
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7. ASCAMP
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COOPER DEVELOPMENT DIVISION

THE Marquardt CORPORATION

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◆ OGDEN DIVISION ◆ POMONA DIVISION
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CORPORATE OFFICES: VAN NUYS, CALIFORNIA

and ship it to an AEC facility in small capsules for irradiation, which will transform it into Curium-242, a radioactive isotope with a half life of 163 days. Martin expects to produce Curium-242 in 1.5-oz batches—more than the total produced so far, according to one engineer. GE is working on more efficient ways to "mine" Cerium-144, Promethium-147, and Strontium-90 fission products from the radioactive wastes generated at the Hanford plutonium plant.

• TRW's Tapco Group, in association with Thermo Electron Engineering Corp., has delivered to the AF design and test specifications for two experimental thermionic generators to be used in solar thermionic power systems. The Tapco work is being carried out under a WADD contract.

MAN IN SPACE

• Washington observers are convinced the Russians tried another "space spectacular" to punctuate Premier Khrushchev's explosive UN visit— either an orbital attempt with a manned vehicle or a shot at Mars. Whatever it was, it apparently failed. So far, no word has trickled down from intelligence sources as to what really happened.

• The U.S. Mercury program is slipping further behind schedule. First Mercury-Redstone shot was postponed during the past month, while the second Mercury-Atlas flight was not expected until this month. Provided the first two Mercury-Redstone flights are successful (first with an artificial "crewman simulator," then with a simian), an astronaut will be committed to the third flight. Probably three or four astronauts will make sub-orbital flights aboard the Redstone, and the first American to orbit will be selected from this group, according to Rep. Overton Brooks, chairman of the House Science and Astronautics Committee.

• Officials of NASA's Marshall Space Flight Center have confirmed that the C-1 Saturn will be used to develop Apollo hardware as an "extra" in the last four flight tests of the Saturn vehicle before it becomes operational in 1964. The three-stage C-1 could re-enter four-ton payloads at escape velocities, simulating return from circumlunar missions, and it could orbit 10-ton Apollo systems for qualification tests.

• The Dynasoar flight-test program calls for 18 vehicles, seven unmanned and 11 manned. Its cost: $495 million. Air drops of an unmanned glider are to begin late in 1962, followed by ground launch of an unmanned vehicle from Cape Canaveral late in 1963, and by the first manned flights late in 1964. Initial landings will take place at a downrange island, possibly Ascension, with Edwards AFB the destination for the final flights.

• Chance Vought Astronautics Div. has been awarded an AF contract to develop a restraint system to protect astronauts against landing impact forces as high as 60 g's . . . Two AF pilots spent more than 30 days in a space cabin simulator at the AF School of Aviation Medicine, thus chalking up the longest simulated space cabin run to date . . . Beckman Instruments has developed a tiny electrode which makes it possible to measure oxygen directly in the human body . . . GE-MSVD has received an AF contract for a design study of a protective full-pressure suit . . . Republic Aviation showed a working model of a 120-lb pressure suit for lunar exploration consisting of a two-piece cylindrical aluminum tunic and torso with legs and arms attached, and with a dome-shaped top section encircled by a 14-in. high plexiglass window.

SPACE VEHICLES

• Rocketdyne has received a $44 million NASA contract for development of a 200,000-lb-thrust hydrogen engine, winning out over four other companies. Designated J-2, the engine is slated for use in advanced versions of Saturn and will be designed initially for single-start capability, although it will be redesigned later for multiple starts in space. The contract provides for a $4^1/_2$-year development and qualification program.

• AF has awarded Aerojet a contract for delivery of Able-Star second-stage boosters for use in future Transit and Courier launches.

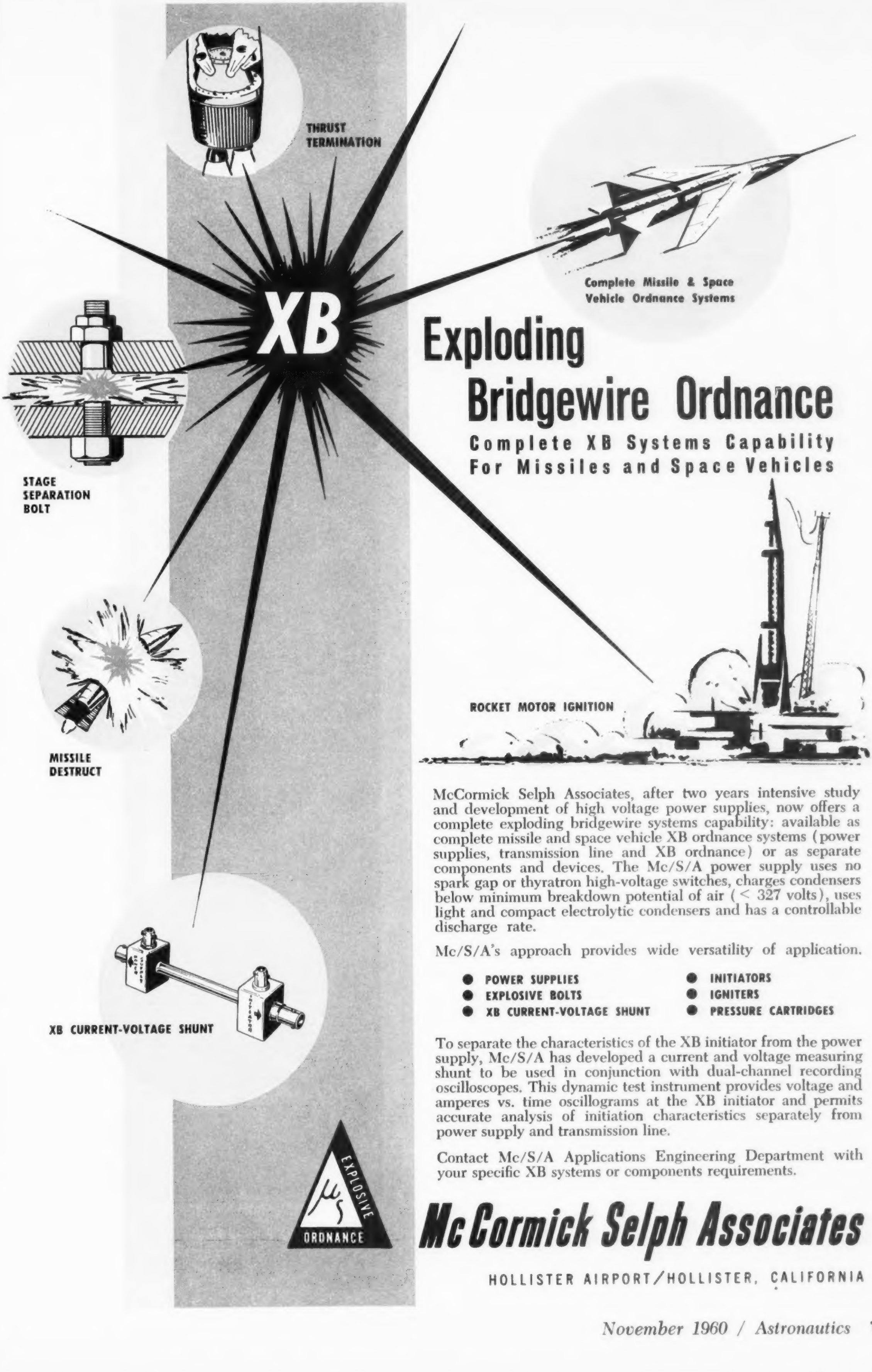
• Saturn industrial conference at Huntsville produced some interesting news, such as: (1) Specifications for a new stage, employing a cluster of four 200,000-lb engines, to be used in the second Saturn vehicle, are in preparation, and a bidders' conference will be held next spring; (2) major opportunities for manufacturers today lie in design of components for use in the lox-hydrogen upper stages of Saturn and in the nuclear rocket using hydrogen as a working fluid; and (3) the Marshall Center will this year begin to contract for part of major Saturn structural assemblies, and eventually all major structural items will be produced by industry.

U.S.S.R. IN SPACE

• In a review of Soviet activity during IGY and the "Cooperation" year (1959) which succeeded it, Anatoli A. Blagonravov reported that the U.S.S.R. had launched 175 sounding rockets, including 158 meteorological rockets to study the upper stratosphere and 17 geophysical rockets for studies between 100 and 470 km. Of the latter, six included spherical, attitude-controlled containers of 367 kg each for optical observations; seven launchings to 210 km included 2200-kg detachable sections consisting of animal cabin and instrument section and a parachute device for returning to the earth; and a total of nine launchings (presumably including the preceding seven) included hermetically sealed cabins with animals and control equipment.

• Thinking bigger than ever, a Soviet scientist has proposed a belt of tiny dust particles around the earth which would reflect light and heat to the northern hemisphere. M. Grodskiy suggests that 1,750,000 tons of potassium particles distributed by rocket in an orbiting belt between 1200 and 10,000 km altitude would "greatly improve the thermal system of the northern hemisphere . . . and have no appreciable effect upon the tropical latitudes."

• A Soviet delegation attended the AGARD propulsion conference held in Varenna, Italy, Sept. 9–12 . . . IAF President Leonid I. Sedov said in Rome in mid-September that man will get to the moon "sooner than one would think" but added that before this occurs an automatic station would be sent to the moon . . . V. Beklemishev of the Soviet Academy of Medical Sciences said that TV photos made of Belka and Strelka in orbital flight in Sputnik V indicate that prolonged periods of weightlessness do not lead to general malfunctions in a living organism . . . Soviet Academician D. Markov, listing some "not insuperable" problems of safe manned space flight, indicated that better methods for regeneration of cabin air during long-duration flights, development of an improved pressure suit, radiation protection devices, perfection of escape devices in case of mechanical failures, and further evaluation of the behavior of an organism under special con-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To separate the characteristics of the XB initiator from the power supply, Mc/S/A has developed a current and voltage measuring shunt to be used in conjunction with dual-channel recording oscilloscopes. This dynamic test instrument provides voltage and amperes vs. time oscillograms at the XB initiator and permits accurate analysis of initiation characteristics separately from power supply and transmission line.
Contact Mc/S/A Applications Engineering Department with your specific XB systems or components requirements.
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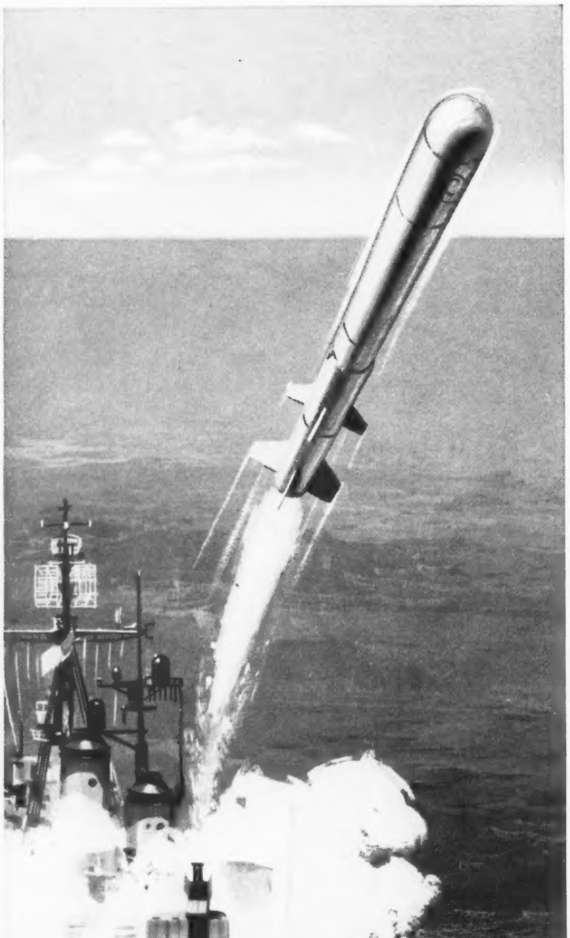
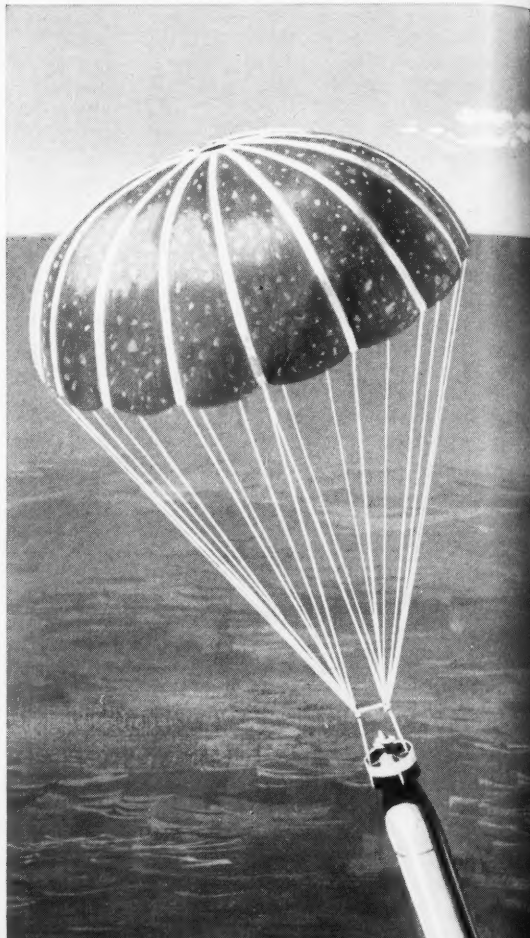
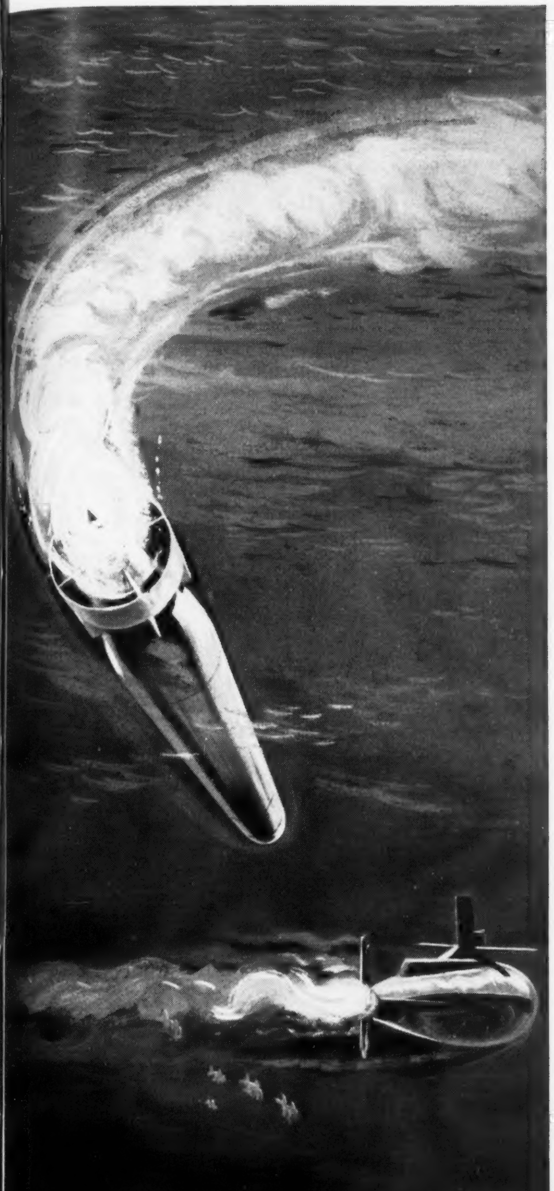


1. Within seconds after detecting an enemy submarine, a shipboard computer automatically charts the sub's course, range and speed . . . then aims the missile launcher. Upon command, a rocket-propelled ballistic missile is fired.



2. The missile follows a ballistic trajectory, shedding its rocket motor and airframe before water entry. When the payload is a torpedo, a parachute blossoms in flight to slow the missile's plunge into waters near the target.



3. After hitting the water, the ASROC torpedo becomes activated by the energizing of a sea-water battery. Then, the missile begins an acoustical homing search from which it locks onto its target and pursues it to destruction.

Swift and precise sequential control of Honeywell's ASROC provides the first long-range anti-submarine weapon

From initial sonar detection through firing and ultimate target contact, ASROC's automatic system delivers an unerringly destructive missile from thousands of yards away—all in a matter of seconds!

Development of ASROC started with an idea and tens of thousands of unanswered questions. Hoping to find the answers, the Bureau of Naval Weapons gave Honeywell, as prime contractor, the responsibility of designing, developing, testing and producing the entire system under technical direction of the Naval Ordnance Test Station.

The ASROC concept was based on present knowledge at the time the program was initiated, but it remained for exhaustive test programs, carried out by the Navy-Honeywell team, to develop ASROC from idea to hardware.

Early in the program, prototype missiles were test fired statically and from moving platforms at the Naval Ordnance Test Station to obtain aerodynamic research information. Engineers measured, recorded and computed items and distances for thrust termination, airframe separation and payload impacts.

Hydroballistic information was obtained from dummy payloads fired into the water from a test stand and dropped from airplanes into a hydrophone range. Calculations on trajectory, hydrodynamic stability and depth-time ratios contributed to design. Throughout the development program, more than 200 test firings were conducted.

The result is an integrated weapon system consisting of an underwater sonar detection device, an electronic digital fire-control computer, a missile launcher, the ASROC missiles and all necessary training equipment.

The facilities of 14 Honeywell divisions are available for development of any complex control problems of missile or aircraft systems and components. If you have a problem in the design of systems or components, call or write: Honeywell, Military Products Group, Minneapolis 8, Minn. In Canada, write: Honeywell Controls, Limited, Vanderhoof Avenue, Leaside, Toronto 17, Canada.

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ditions (long periods of darkness, swift transitions from dark to light, etc.) are high-priority items in the U.S.S.R. *Krassnaja Zvezda,* Red Army newspaper, in an article on U.S. space activities, provided some figures which indicate weight of the cabin used in the Sputnik IV and V experiments to be about 2520 kg . . . A jet excavator, with a working capacity of 4000 tons of earth per hour is now operating in Kiev . . . An acoustic thermometer, for use in measuring upper-atmosphere temperatures by means of sound, has been developed in Moscow and has already been used successfully at altitudes up to 28,000 m . . . The Russians are showing a good deal of interest in bioelectric controls and recently demonstrated its possibilities in space by outfitting a patient with an artificial arm and showing how easy it was for the patient to write on a blackboard with the device.

NASA

• Civilian space boss T. Keith Glennan indicates that the NASA budget request going to Congress next January will top $1 billion, and that by 1965, it will have exceeded $1.5 billion and will be approaching $2 billion. The agency was voted $915 million for the current fiscal year.

• A new Aeronautics and Astronautics Coordinating Board has been established to coordinate civilian and military space activities in place of the National Space Council and the Joint Civilian-Military Liaison Committee. With Hugh Dryden, NASA Deputy Administrator, and Herbert York, Deputy Director of Defense R&E, as co-chairmen, the board will "review planning to avoid duplication; coordinate activities of common interest; identify problems requiring solution by either NASA or DOD and insure a steady exchange of information."

• NASA selected Krugersdorp, South Africa, as the site for the third of its deep-space instrumentation facilities. It will build two 85-ft steerable antennas at Krugersdorp to transmit commands to space probes and receive information. Cost is estimated at $2–4 million.

SPACE WEAPONS

• AF has invited proposals on a feasibility study of Project Saint, a satellite capable of intercepting, inspecting, and identifying an unknown satellite. Initial emphasis will probably be given the space rendezvous problem, with the sensors coming later.

• Lt. Gen. Roscoe Wilson, Deputy AF Chief of Staff for Development, believes a space defense against hostile ICBM's is more promising than the Army's Nike-Zeus, even though a space system might not be available until the end of the next decade. A space system, such as a satellite armed with heat-seeking missiles, could strike hostile ICBM's during the powered portion of their flight, before they could change course or release decoys. Nike-Zeus, on the other hand, is confined to the terminal portion of the missile's flight, when many countermeasures may be taken to spoof the defense, Wilson said.

SATELLITES

• AF was successful in its second try at orbiting the Army's 500-lb Courier delayed-repeater communication satellite. Placed in a low-inclination, nearly circular, 650-mi orbit, the complex electronic package demonstrated its ability to move up to 2 million words a day between Fort Monmouth, N.J., and Ponce, Puerto Rico. Courier's four UHF channels and five magnetic recorder-reproducer systems can simultaneously receive, store, and transmit 68,000 words a minute.

• More advanced than Courier is the Army's $174 million program to develop the Advent 24-hr equatorial communications relay satellite. This will be a 1000-lb package with 400 voice channels which may go into its stationary orbit in 1963. The experimental Advent will be operated with two ground stations (one at Camp Roberts, Calif., the other at Fort Dix, N.J.) and one shipborne station to demonstrate its operational effectiveness as a real-time relay device.

• Lt. Gen. Bernard A. Schriever, AF ARDC chief, has announced further postponement of a Discoverer primate shot until December. He had originally predicted September for the attempt, but it turned out that no "house" had been designed for the simian, a 6-lb rhesus monkey to be supplied by the AF School of Aviation Medicine. GE was given the task of designing a couch and life-support system to fit the Discoverer recovery capsule.

• NASA's Marshall Space Flight Center is scheduling two more Juno II satellites in November and December. First is a payload of radiation instruments to be placed in a highly elliptical orbit. The second will be a "top-side sounder" to study the ionosphere.

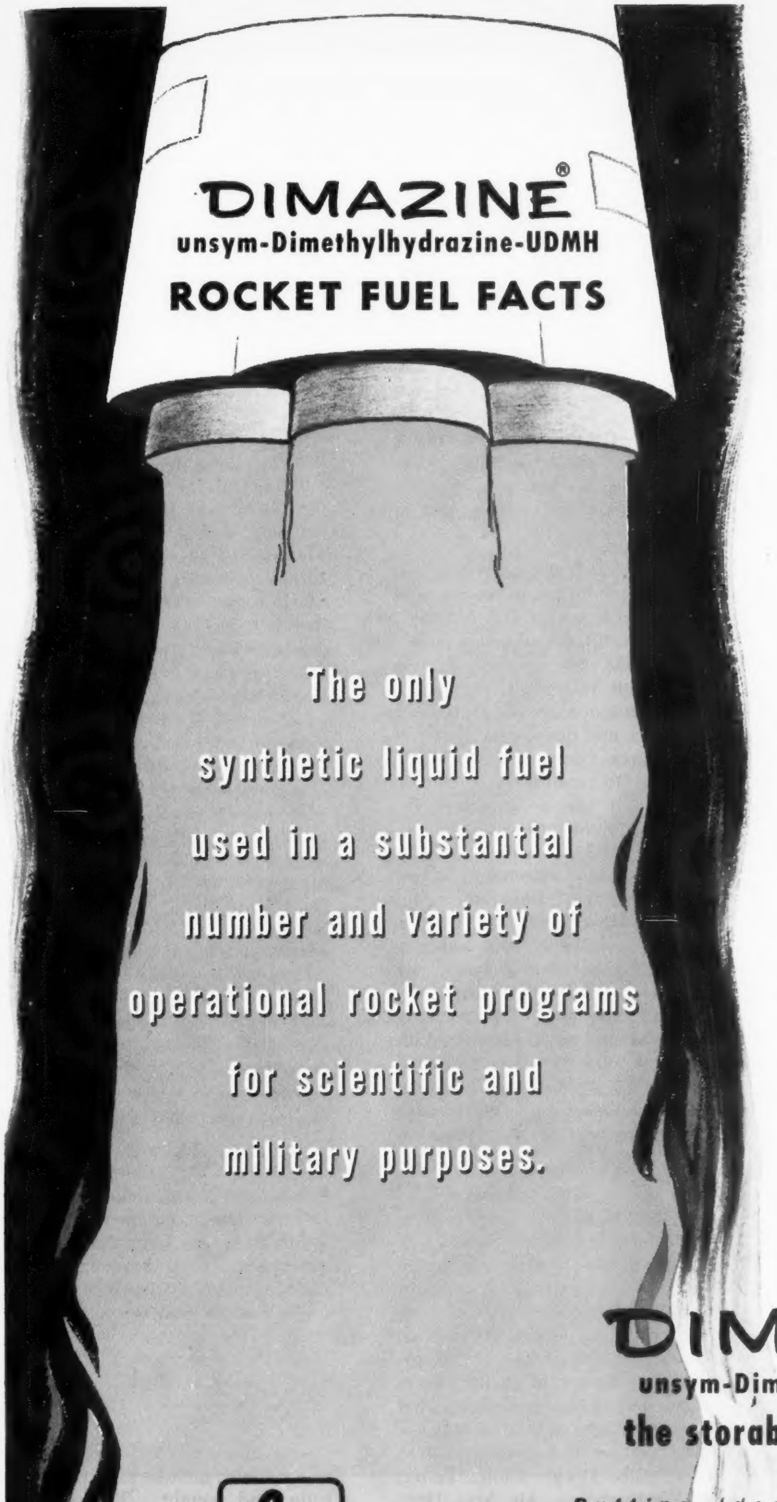
• NASA will procure eight Thor-Agena-B launching vehicles for use at the Pacific Missile Range in orbiting payloads developed by the Goddard Space Flight Center. Tentatively earmarked for the Thor-Agena boosters are four Nimbus weather satellites, the Polar Orbiting Geophysical Observatory (POGO) and the Canadian Top-side Ionospheric Sounder. The vehicle will be able to place 1600 lb in a 300-mi orbit or 850 lb in a 1200-mi orbit.

• Solar radiation pressure—about 0.02 oz—will force the Echo I satellite back into the atmosphere in about a year, according to NASA. Perigee of the 100-ft aluminized mylar sphere will oscillate up and down in the meantime, reaching a low of 716 mi in mid-December and climbing to 980 mi in mid-April, as a result of solar pressure. The sphere has been so successful as a communications reflector that NASA will probably drop its plan to place two more 100-ft spheres in polar orbits. Instead, it will use some form of rigidized sphere, perhaps larger than Echo I, on its next launch.

• NASA invited 21 countries, including Soviet Russia, to participate in the Tiros II weather satellite experiment. It suggested that meteorologists might want to conduct intensified local observations in time with satellite passes in order to correlate cloud-cover data obtained below and above the clouds.

• Alden Electronic has received a Weather Bureau contract to adapt a number of facsimile weather map scanners and recorders to send and receive Tiros II cloud-cover photos at 18 key receiving stations and two transmitting stations of the national high-altitude facsimile weather map network.

• Baird-Atomic has delivered the first of a series of infrared surveillance satellite payloads to Lockheed's Missiles and Space Div. for use in the Midas program . . . Armour Research is building a prototype satellite instrument package for WADD designed to monitor the electromagnetic environment of the satellite over selected ranges of the frequency of the spectrum as it passes through space, and thus yield information relating to the design of future space communication systems.



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• NASA will negotiate a $23 million contract with Grumman Aircraft to design, develop, and build two 3200-lb Orbiting Astronomical Observatories to gather X-ray, ultraviolet and infrared celestial data obscured by the earth's atmosphere. First of the OAO satellites, equipped with a 36-in. reflecting mirror, will be launched into a 500-mi circular orbit from Cape Canaveral late in 1963. The octagonal satellite will be 9.5 ft high and 6.5 ft in diam and will have two sun-oriented paddles carrying arrays of solar cells generating 350 watts of electricity. The OAO package which Grumman will build is scheduled to become NASA's basic heavy-duty spacecraft; the civilian space agency said the structure will have a standardized shell containing power, stabilization and orientation gear, and telemetry equipment sufficient to support up to 1000 lb of scientific experiments. This is expected to reduce sharply the lead time between inception of a space experiment and its final launching.

PUBLIC OPINION

• A recent survey conducted by the Harvard Business Review indicates a large majority of business executives strongly support a vigorous U.S. space program, even if it means foregoing a tax cut. They also feel that space research will have a revolutionary effect on U.S. economic growth and will provide industry with important new technical knowledge and products. The survey—one of the first definitive samplings of public opinion of the U.S. space program—was made through a questionnaire sent to some 2000 business and professional men, less than 30 per cent of whom had a direct business involvement in the space program. Some 73 per cent of those responding thought space research was more important than cutting taxes, while space research was preferred to more leisure and consumer goods, shorter working hours, power plants and dams, and foreign economic aid. Only hospitals, medical research, and education took precedence over space research expenditures. The reasons for space research were listed in this order by respondents: Pure science, military and political control of space, tangible economic payoffs, and prestige vis-a-vis the Soviet Union. Some 43 per cent thought the U.S. was about even with the Russians in the space race, 35 per cent thought Russia was still ahead and 22 per cent thought the U.S. was ahead.

INDUSTRY

• Besides making clear the extent to which it is contracting work to industry—up to 85 per cent of its funding—the management of the NASA Marshall Space Flight Center had some important comments on reliability goals during the Industry Conference on Saturn at Huntsville late in September. MSFC will require the manufacture of small but critical lots of hardware by semi-automatic means to keep reliability high. Moreover, it will expect industry to take a stronger lead in insuring the reliability of its products. Default of industry in this area will force the government to procure material from a select, rather than an open, list of vendors.

• A policy debate on public vs. private exploitation of space was expected to follow NASA Administrator T. Keith Glennan's proposal that satellite communication systems be left to private enterprise, the civilian space agency continuing its research and development efforts in this area "only so long as is necessary to assure that timely development of a commercially feasible communications system will be completed by private industry." In his first policy statement on this subject, the Administrator said NASA will support technically promising proposals from industry on a "cost-reimbursable basis," by which was apparently meant government launching and tracking services at cost to industry. With a fleet of superior space "trucks" in the making, NASA would seem in a good position to broaden industry participation in the space program in this way.

• The greater emphasis that will be given ballistic-missile defense (see the October 1960 *Astronautics*) was underscored last month by the Dept. of the Army announcement that it has awarded six contracts, each for $250,000, to the following groups of companies for feasibility studies of a field-army defense system against ballistic and guided missiles: (1) Convair-Pomona, Calif., with Burroughs Great Valley Laboratory, Paoli, Penn., and Westinghouse Air Arm Div., Baltimore, Md.; (2) General Electric Co., Radnor, Penn., with Chrysler Corp., Detroit, Mich. ;(3) Hughes Aircraft, Fullerton, Calif., with North American Aviation, Downey, Calif., Aerojet-General Nucleonics, San Ramon, Calif., and R. G. LeTourneau of Longview, Tex.; (4) Martin-Orlando, Fla., with W. L. Maxson Co., New York, N.Y.; (5) Raytheon, Bedford, Mass., with IBM, Bethesda, Md.; Dunlap & Associates, Stamford, Conn.; Avco, Wilmington, Del., and Northrop Corp., Hawthorne, Calif.; and (6) Sylvania, Waltham, Mass., with Aeronutronic, Newport Beach, Calif.

MATERIALS

• The largest molybdenum sheet ever produced—48 in. wide and 105 in. long, with a thickness of 0.060 in.—is now available on a mill-order basis from the Refractomet Div. of Universal-Cyclops Steel Corp. . . . NASA has organized a Materials Research Programs Div., headed by George C. Deutsch, formerly head of the Refractory Materials Branch of NASA's Lewis Research Center . . . Pfaudler Div. of Pfaudler Permutit has introduced a new ceramic metal composite called Nucerite, which is said to possess unusual resistance to high-temperature corrosive vapors (1200–1400 F) while representing a significant advance in such properties as mechanical strength, thermal shock and abrasion resistance, heat conductance and high temperature stability . . . Studies under way at Bell Telephone Labs have uncovered what is said to be one of the most efficient thermoelectric materials yet developed—silver antimony telluride ($AgSbTe_2$) . . . Nuclear Corp. of America, meanwhile, is plumping for gadolinium selenide, which, when prepared under specific conditions, is said to have a very high thermal output voltage and to be capable of operating at temperatures up to 1500 C.

AIR AND SPACE

• U.S. and Soviet delegates to the Intl. Aeronautical Federation meeting in Barcelona last month reached agreement on standards for judging world space-flight records and thus took an important step toward solution of the air-space controversy. Under the agreement, flights would have to reach an altitude of 62 miles to qualify as space flights, with records to be recognized for manned rocket vehicles only. Records would include duration, altitude, and weight. This was the first instance in which U.S. and Soviet representatives reached an accord with regard to the definition of "air" and "space," and may herald the beginning of international agreements on such definitions for legal purposes. ♦♦

At $00^h00^m01^s$ GMT, November 1, 1960, Martin logged its 724,620,000th mile of space flight

TITAN—*50 miles up: Official USAF Photo*

***Air Force-Martin Titan,** giant American ICBM, has been chosen for a key role in space exploration. One of its first missions will be to launch USAF Dyna-Soar — manned aerospace craft.*

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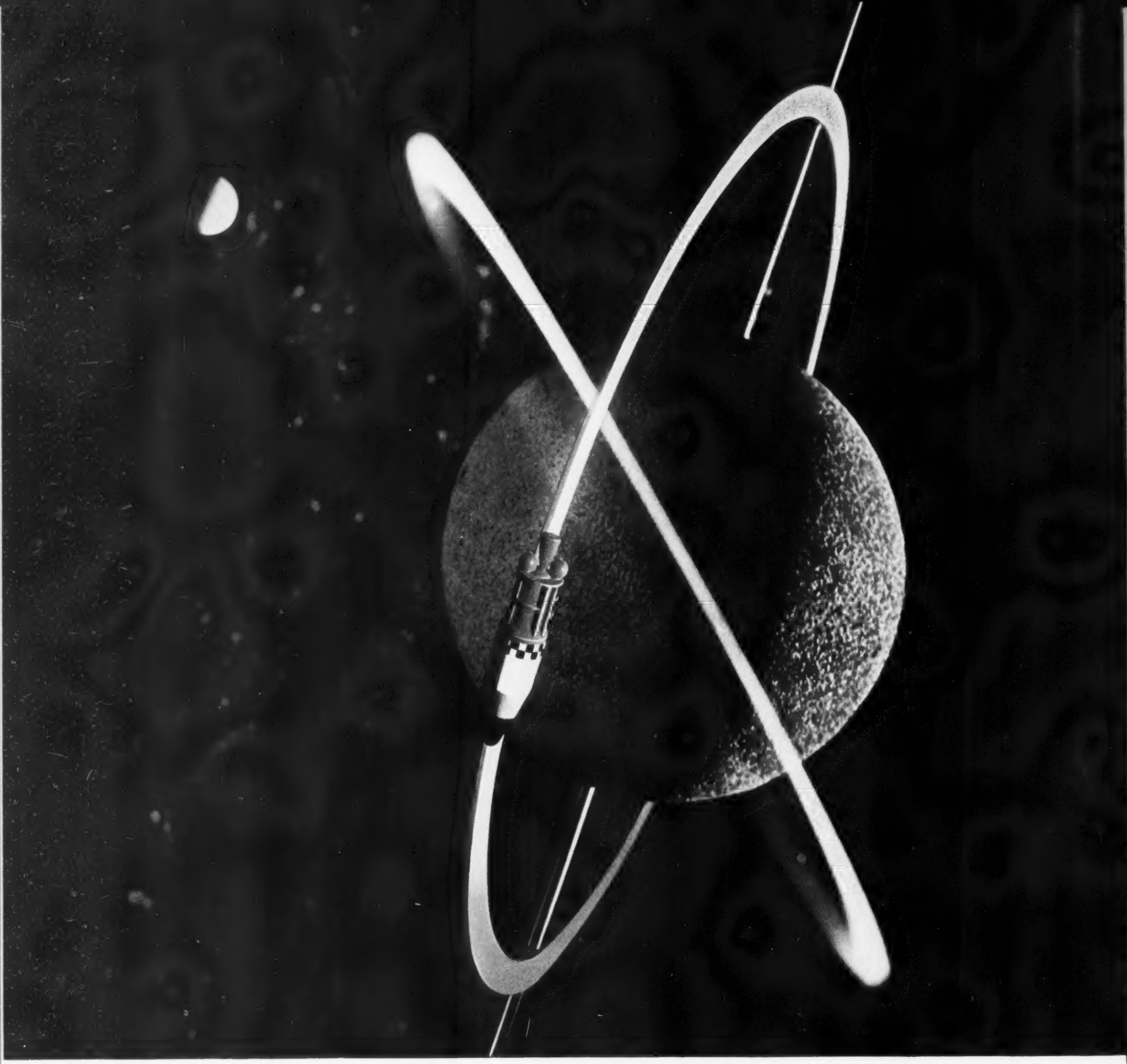

Bell-powered Agena satellites in orbit — symbolized.

THE ENGINE WITH THE FUTURE

Reliability . . . Efficiency . . . Flexibility.

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Vast sums of money and vital scientific data ride on these built-in attributes of Bell Aerosystem's rocket engine for Lockheed's Agena satellite, second stage of the Air Force Discoverer series.

The Agena engine, designed with space in mind long before space became a household word, has fulfilled its every mission and has placed more tons of useful payload into orbit than any other power plant. Its operational reliability is backed by six years of development and 5,000 test firings.

This Bell engine now has re-start capability — the first in the nation. This means that its satellite can change orbit **in space** without the penalty of extra engines. Presently in production, this engine also is adaptable to new fuels and new assignments and, consequently, is programmed for important military and peaceful space ventures of the future.

Agena's engine is typical of the exciting projects in Bell's rocket propulsion center. It is part of the dynamic new approach of a company that's forging ahead in rocketry, avionics and space techniques. These skills serve all government agencies. Engineers and scientists anxious for a new kind of personal challenge can find it at Bell.

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For the record

The month's news in review

Sept. 3—NASA says skin wrinkling probably causes fluctuations in Echo I's brilliance.

Sept. 4—AF announces it has sent signals to a 300-mi altitude via an around-the-horizon emergency communications system aboard an Aerobee rocket.

Sept. 10—X-15 flown to 80,000 ft at more than 2100 mph in stability test.

Sept. 13—Discoverer XV hurled into orbit, ejects 300-lb capsule on 17th orbit.

—Aeronautics and Astronautics Coordinating Board formed to coordinate U.S. military and civilian space programs. Co-Chairmen are Herbert F. York, DOD director of research and engineering, and Hugh L. Dryden, NASA deputy administrator.

Sept. 14—Nike-Hercules "kills" sister missile at 19-mi altitude.

Sept. 15—Two AF pilots complete record-breaking, 30-day stay in simulated space cabin.

Sept. 17—NASA says it is working on development of an off-the-shelf carry-all vehicle for space explorations.

Sept. 19—AF shoots Atlas 9000 miles downrange.

—Navy sends Nerv (nuclear emulsion recovery vehicle) sounding rocket 1200 mi high and recovers its 83-lb capsule.

Sept. 21—AF test-fires Blue Scout Junior to 16,600-mi altitude. Malfunction blocks transmission of radiation data back to earth.

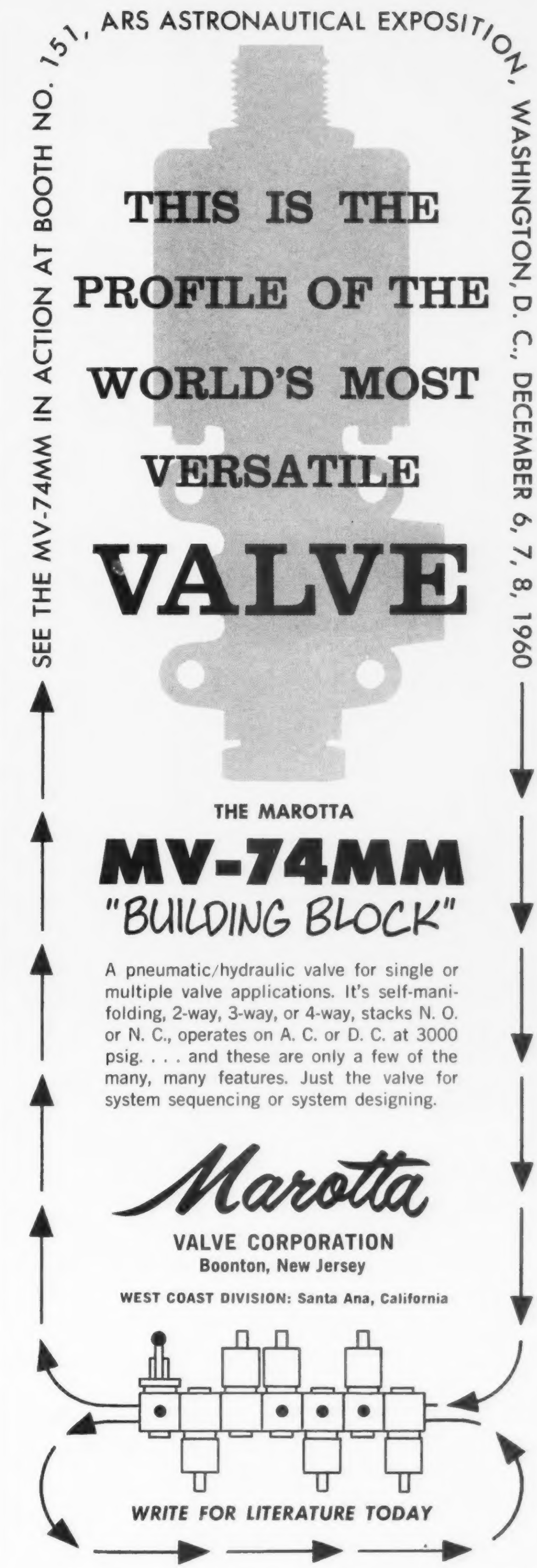
Sept. 25—Atlas-Able lunar probe fails, presumably because of abnormal ignition of middle stage.

Sept. 27—Data from Explorer VII reveals relation between heat earth gives off and air pressure in space.

Sept. 28—Titan hurls dummy warhead 5000 st. mi into Atlantic.

Sept. 29—FCC rejects proposals that it immediately reserve specific radio frequencies for space communications.

—AF attempt to fire Titan 10,000 mi falls 4000 mi short of goal.



One of a series

Catching the Drift of Gyro Bearings

The fantastic accuracies needed by inertial guidance systems for space flight depend on the suppression of gyro drift, the tendency of a gyro to precess from minutely occurring internal torques. Particularly puzzling has been the problem of "jogs," or sudden axial shifts, within gyro spin-axis bearings. Shifts of but one ten-millionth of an inch can cause serious steering error.

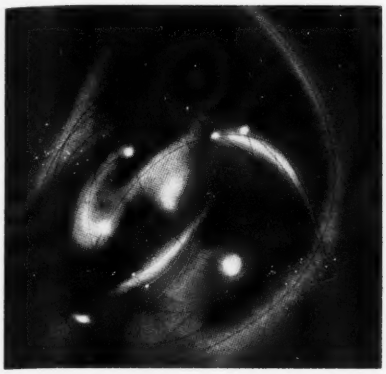
Specialists at the GM Research Laboratories have found that the real key to drift lies in the thickness and distribution patterns of bearing lubricating films. Only a tenth of a milligram of oil — equivalent in volume to less than two-thousandths of a drop of water — is required in a gyro bearing, but even this amount unevenly distributed may cause jogs.

Conducting unique studies of single bearings apart from rotor assemblies, GM Researchers use a hydrostatic spindle and special instrumentation to take film-thickness measurements they compare with hydrodynamic theory. Jogs, due to excess oil supply, have been analyzed in relation to surface oil transfer and separator feed control, ball spin orientation, displacement, and differential heating and ball wander.

This experimental and analytical approach is achieving progress toward jog-free, stably distributed, and suitably thick oil films required in high-precision bearings. It is a further example of the critical and advanced research General Motors carries out in seeking "more and better things for more people."

General Motors Research Laboratories
Warren, Michigan

The fluoresced streaks show the disturbed "wake" of the lubricating film during bearing operation. The active part of the film, too thin to fluoresce visibly, averages ten-millionths of an inch in thickness.



COVER: *"Space Design No. 2," an original painting by the outstanding New York artist George V. Kelvin. (Full-color ASTRO cover plaques, 11 x 12 in., are available from ARS Headquarters for $2.00 each.)*

Astronautics

NOVEMBER 1960

State of the Art

The primary purpose of *Astronautics*—to provide engineering leadership for the nation's space and missile programs through the dissemination of basic technical information—has seldom been better served than in this issue, the *Third Astronautics Annual.*

The four feature articles offer provocative comments about important features of these programs, and peer into the future in order to examine likely developments during the next few years. Maj. Gen. O. J. Ritland provides a full-scale examination of the AF ballistic-missile program, Abe Silverstein previews the nation's civilian space program for 1961 and beyond, Maurice H. Stans carefully analyzes the funding of U.S. civilian and military space programs, and Wernher von Braun turns his attention to the much-discussed "optimum" program and what it means.

The preview of the ARS 15th Annual Meeting and Astronautical Exposition clearly delineates the tremendous scope of the Society's activities at the present time, and indicates a growing tendency to make the Annual Meeting one which ties together the many disciplines which are today encompassed by the word "astronautics."

However, it is the 20 State-of-the-Art Reports compiled by the ARS Technical Committees which form the heart of the issue, and make it a permanent reference work which will be retained by readers who wish to keep abreast of important developments in these several disciplines. Assembled by some of our leading astronautical engineers and scientists, and accompanied in most instances by selective bibliographies or references, these reports combine to form a comprehensive survey of where we stand today and of the many difficult problems we still face.

The scopes of the ARS Technical Committees, listed on page 56, indicate quite clearly the breadth of the field now served by ARS. Improving communication between specialists in these many areas is a fundamental goal of the Society.

The *Third Astronautics Annual* represents an important step forward in assuring this much-needed communication.

Howard S. Seifert
PRESIDENT, AMERICAN ROCKET SOCIETY

Funding the space program

Public interest, domestic technical competition, the international scene, and our national economy—all influence a budget aimed at giving the space program long-term vitality

By Maurice H. Stans

BUREAU OF THE BUDGET, WASHINGTON, D.C.

Maurice H. Stans has been Director of the Bureau of the Budget since March 1958, after having served for six months previously as Deputy Director. His government service dates back to 1953, when he served on a task force which assisted the House Appropriations Committee in reviewing the federal budget for FY 1954. Subsequently, he was engaged for more than a year in a special study of postal fiscal systems and accounting practices for the Postmaster General. Before coming to the Bureau of the Budget in September 1957, he had been Deputy Postmaster General for two years. Prior to 1955, he was executive partner in the national accounting firm of Alexander Grant & Co. He was elected to the Accounting Hall of Fame this year, is a past president of the American Institute of Certified Public Accountants and received the Tax Foundation Award for distinguished public service last year.

ONE OF MAN'S most exciting prospects for adventure and the collection of knowledge in the coming decades is the exploration of space. Under the direction of NASA, the U.S. civil space programs have made remarkable strides in the last two years. An extensive amount of scientific information has been collected and released for the use of all nations, and progress has been made in civil worldwide meteorological and space communications applications which may some day materially influence international living conditions and understanding. It also appears that the use of space offers advantages to us militarily. Among projected military applications, all of which are well along in the development cycle, are reconnaissance, early-warning, navigation, and communications space systems.

A Long-Range View Necessary

The civil space programs must be viewed as long-range R&D programs aimed at scientific and applications goals, some of which are ten or more years in the future. We are funding these programs for the long haul. Civil operational systems, such as those for meteorology and communications, will be operated and probably funded in whole or part by industry or other government agencies, such as the Weather Bureau, after NASA has proven their operational feasibility.

It is apparent that there are both direct and indirect benefits from this civil program. The direct benefits are in the form of new knowledge, operational civil applications, and international prestige. The large dollar amounts needed to get these direct benefits, however, are competitive with other programs, scientific and otherwise, which are supported by the government. To some, it does not appear that the direct benefits we are achieving are worth the \$975 million which has been appropriated for the civil space program in the current fiscal year—\$915 million for NASA and \$60 million for related work by AEC.

However, there are indirect benefits from the space program as well, which may be equally as important to us nationally as the direct. It is interesting to note that the civil space programs are supported strongly by many leading scientists, engineers, and administrators involved in other programs. It appears that this support

derives in large part from the technological and scientific "fallout" which has accrued and will continue to accrue from the space program in virtually every field of scientific and technological importance.

What the aircraft and missile programs have been as pacesetters for science and technology in the recent past, the space program, both civil and military, is today. On balance, it appears that the U.S. has a logical, well-balanced civil space program and that the benefits, on hand and expected, are substantial.

The military space programs, for which a total of $561 million was appropriated in FY 1961, must be viewed somewhat differently because they are designed to use space to meet military operational requirements. There are two stages in the funding of military space programs. After a decision is made that space might provide unique or greatly improved capabilities in meeting specific military requirements, such as reconnaissance or early warning, R&D programs are undertaken to prove, ultimately by developmental launchings, the feasibility of using space to meet these requirements. This first stage is generally comparable with the R&D work being done by NASA on civil communications and meteorological applications.

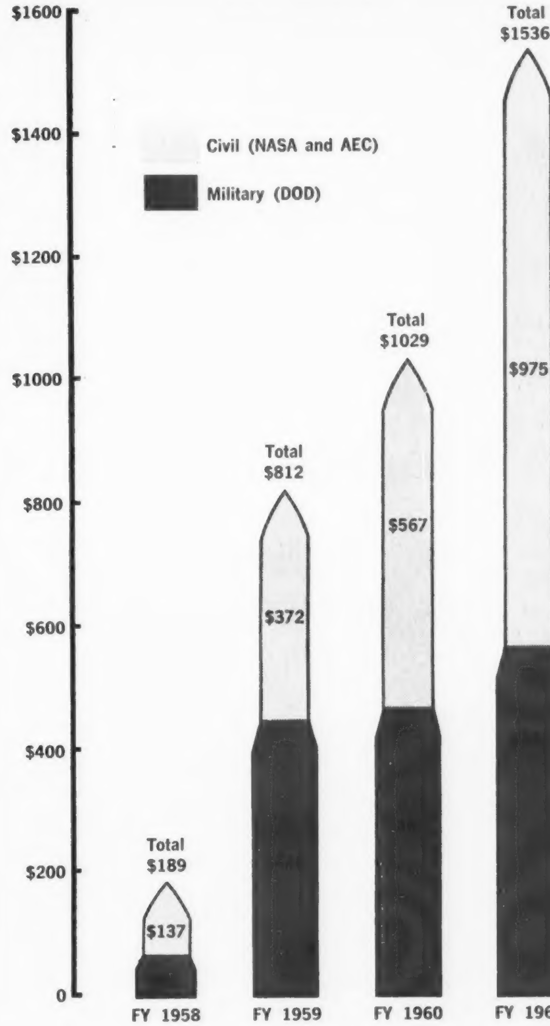
On the basis of progress in the development programs, the advantages of the use of space, as opposed to other more conventional means of accomplishing a specific mission, are then assessed by the senior officials in DOD and their scientific and military advisers. If it is concluded that the space environment provides the best way to accomplish a mission, the decision is made to start the second or operational funding stage. The military application programs differ from the civil in that the military will be funded and operated by DOD while the civil applications, as I have said, may well be funded and operated in whole or part by industry, by government agencies, or by both, depending on the nature of the system.

Let us now examine some of the problems the executive branch and, later in the budget cycle, the legislative branch of the government must face each year in funding the space program.

Coordinating the Diverse

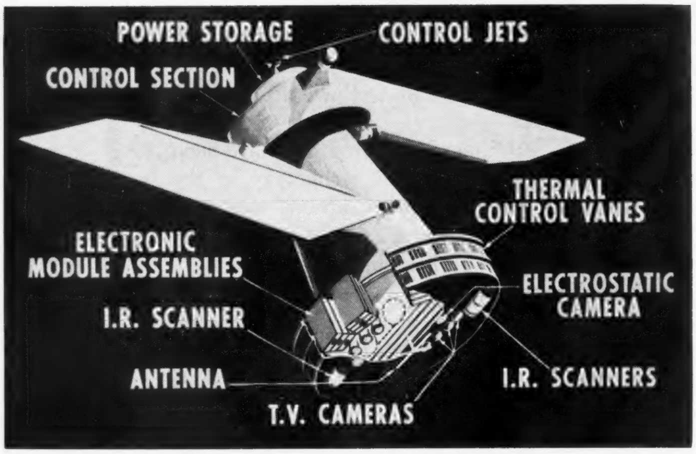
First, there is a group of problems connected with coordination of funding of the major divisions into which our space programs fall—the civil and the military. The civil and military programs have different objectives but also have some marked similarities from a financial management point of view which make close coordination in program planning and funding mandatory.

New Obligational Authority for Space Activities (In $ millions)



A brief outline of the history of these space programs provides a background for understanding some of the facets of these problems. While much of the advanced research and technology which made possible our early accomplishments in space resulted from the work of the National Advisory Committee for Aeronautics, NASA's predecessor, the early space programs, starting with Vanguard, were all conducted by DOD. After the firing of the first Sputnik, and during the interim while NASA was being created as a reflection of the U.S. desire to have the scientific exploration of space done under civilian direction for peaceful purposes, DOD pushed ahead on (CONTINUED ON PAGE 146)

The Nimbus meteorological satellite will be launched and stabilized in a polar orbit. The large vane-like structures are solar panels. Work on Nimbus has already started.



Progress in space flight

U.S. civilian space program takes a rich and varied form as the attack is mounted on man's new realm of action

Abe Silverstein is NASA Director of Space Flight Programs. He brings to this key position in the civilian space program an exceptional background in aeronautics and rocketry as they have developed in the U.S. A long-time member of the NACA, having joined in 1929 the organization which underlies NASA, Dr. Silverstein helped design the Langley full-scale wind tunnel, directed that facility, moved to the Lewis Laboratory in 1943 where he organized and directed research in its new Altitude Wind Tunnel, in 1949 became director of research at Lewis and then associate director of Lewis in 1952, and between then and 1958, when he assumed his present position with NASA at its formation, participated in many key government committees concerned with rocketry and astronautics, and directed a good portion of this country's research on turbojet, ramjet, rocket, and nuclear-propulsion systems.

By Abe Silverstein

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, D.C.

The NASA program was highlighted in 1960 by a number of outstandingly successful pioneering space flights. Emphasis this year has been given to satellites which have demonstrated for the first time the application of space technology to the practical problems of global communications and weather forecasting.

President Eisenhower's message transmitted on the first orbit of the Echo I satellite over the U.S. emphasized the keynote of the NASA program.[1] He said, "The program is being carried forward vigorously by the United States for peaceful purposes for the benefit of all mankind."

Not as spectacular as the flight program, but even more important for strengthening the continuing national space program, have been the development in depth of the NASA organization and facilities, the establishment of working relationships with industry and universities on future programs, the growth in the reservoir of scientific and technological information on which future progress depends, the initiation of an international program, and the continued development and contractual implementation of a long-range plan for space exploration.

A brief account of some 1960 achievements should be of interest. The Tiros satellite launched on April 1, 1960, was designed to transmit pictures of the earth's cloud cover. On its fifth pass, Tiros photographed a storm centered over Nebraska. In the following few days it photographed a storm 400 miles west of Ireland, one 800 miles west of California, and a tropical storm near New Zealand. Tiros pictures showed that spiral cloud band formations, similar in

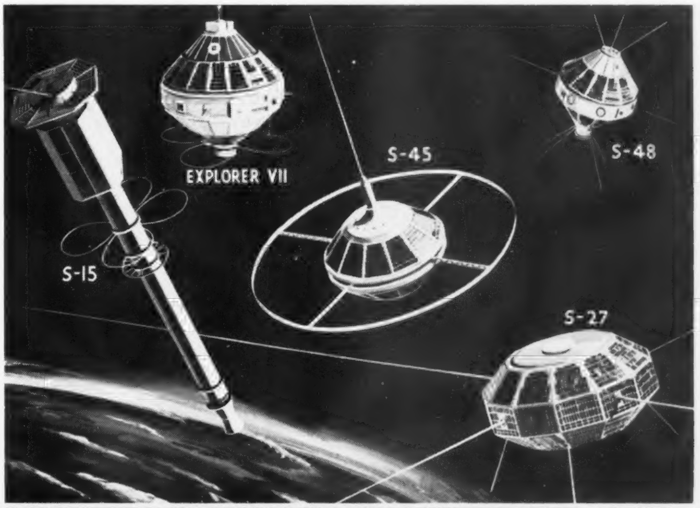
appearance to precipitation bands characteristic of hurricanes, exist in storms outside the tropics. Storms as large as 1500 mi in diam were clearly depicted. The Tiros photographs also revealed for the first time the large degree of organization that exists in cloud systems over the earth. During its 78 days of useful life Tiros transmitted almost 23,000 photographs. The full significance of the information will not be revealed for some months, as meteorologists in the Weather Bureau and elsewhere work to correlate cloud patterns with other meteorological data.

The goals of our work on meteorological satellites are to provide information necessary to increase the level of our understanding of atmospheric behavior and to develop the principles of a synoptic worldwide meteorological observation system using satellites. Another Tiros will soon be launched which will have, in addition to the television cameras of Tiros I, infrared equipment to measure the earth's heat balance and the distribution of radiation in specific spectral regions.

This year the development of an advanced meteorological satellite, Nimbus, has been started. It will weigh more than twice as much as Tiros I, be earth-oriented in a polar orbit, and contain TV cameras, infrared scanners, and other scientific experiments. The series of Nimbus developmental satellites should lead to an operational satellite system.

Echo I—A Major Step

The Echo I communications satellite was launched on Aug. 12, 1960. Since transmission of the President's message, basic experiments at several frequencies and with various forms of wave modulation have been conducted. Pictures have been sent in facsimile between sta- (CONTINUED ON PAGE 140)



Some NASA probes and satellites—past, present, and future: Vanguard III, Explorer VI, Pioneer V, and Tiros I have served their mission but remain in orbit. Experiments are still being conducted on Echo I and Explorer VII. Scheduled for the next few months are a lunar orbiter (Atlas-Able V); S-30, a satellite to measure properties of the ionosphere; and S-15, a satellite to measure gamma rays. Future satellites include S-16, a solar observatory; S-3, a satellite to study energetic particles in the Van Allen belts, particles from the sun, and cosmic rays; P-21 and P-26, geophysical probes to study electron distribution in the ionosphere; S-6, a satellite to study upper-atmospheric structure; P-14, a probe to study magnetic fields; S-45, a satellite to study the ionosphere; S-48 and S-27, two ionospheric topside sounder satellites, the latter being prepared by the Canadians; and S-51, a satellite to be instrumented by the United Kingdom.

What is an optimum program?

Optimization in the missile and space-flight field should put the criterion of "maximum chance of success within schedule and dollar limitations" ahead of all others if that success is to be achieved

By Wernher von Braun

NASA MARSHALL SPACE FLIGHT CENTER, HUNTSVILLE, ALA.

Wernher von Braun's career in rocketry dates back 30 years, to the time when, as a youngster of 18, he joined the German Society for Space Travel. Technical director of Germany's Peenemuende Rocket Center from 1937 to the end of WW II, he came to the U.S. under contract to the Army Ordnance Corps in 1945 and, after working on captured V-2 launchings at White Sands, became project director of an Army Ordnance missile development unit at Ft. Bliss which employed 120 of his Peenemuende colleagues. In 1950, the entire group was transferred to Redstone Arsenal, then designated the development center for Army missiles, with Dr. von Braun as director of development operations, a post he continued to hold when the Army's long-range ballistic-missile activity was shifted to the newly formed Army Ballistic Missile Agency early in 1956. He continued in that capacity until July of this year, when the ABMA Development Operations Division was transferred to NASA and the Marshall Space Flight Center came into being with Dr. von Braun as Director.

THE PURPOSE of this short treatise is neither to criticize nor to crusade. My objective is simply to clarify some of our trade semantics. Maybe this will result in a few broad suggestions.

One has a hard time these days finding an ad or a pamphlet about a rocket component without some reference to the term "optimized." All our missile and space systems are "the result of careful optimization studies." Even our national defense and space programs are described as "optimum programs within the available resources."

Just what is an optimum program? What is an optimized missile system? What is an optimized rocket engine, an optimized structural design, or an optimized pipe connection?

When I buy a washing machine, an intelligent definition of the term comes relatively easy: The optimum machine is the one that gives me most service for the minimum amount of capital and operational expenditure. But what, for instance, is an optimum long-range missile system? Is it the one that delivers the biggest bang with minimum takeoff weight? Or is it the one with the greatest flexibility and maneuverability in tactical deployment? Or is it the least expensive one? If so, the more specific question arises: The least expensive to *develop* or maybe the *cheapest per round* in quantity production after substantial pilot production? Or is it possibly the system that can be developed in the shortest time? Or the one that, considering the intelligence appraisal of the capabilities of a potential enemy, promises the longest possible relative superiority and operational usefulness? Or is an optimum missile system possibly the one that places main emphasis on reliability?

Certainly, all these criteria are important and desirable. But the sober fact is that, more often as not, they contradict one another, and it is not possible to come out with a solution which is optimum on *all* counts.

Take reliability, for instance. Needless to say, we are all for it, like we are all for virtue, and thus I am on safe ground when I put it high on my priority list. It is very fashionable these days to set up separate organizational elements in development teams solely devoted to component and systems reliability. And, lest you think I am cynical about it, let me hurry to add that a statistical reliability analysis is a very powerful tool in determining a good systems concept. Also, the combined effect of low production rates, great number of parts, and exotic in-flight environmental conditions, which are so common to all missile and space carrier projects, make it absolutely mandatory to police strictly the safety margin between actual environment and environmental failure limit of every single component.

Yet remember that on the highway safety does not begin with the police but with the driver. A solely statistical approach to the vice of unreliability is just as limited in effectiveness as the quotation of accident statistics for the purpose of improving driving safety. It fails just as badly to raise the moral standards as Dr. Kinsey's famous book on a set of different vices. Reliability is rather the result of an almost religious vigilance and attention to detail on the part of every member of a development team, and the most important aspect of every successful reliability program is to keep this vigilance alive. Reliability begins with the designer.

But the designer, always aware that he is expected to "optimize," is squarely confronted with what we may call the "competitive dilemma." He knows his company has a great body of practical experience with a certain type of flex hoses for high-pressure tubing. Yet there is that trade journal ad recommending a new type of flex hose of some exotic material which is 40 per cent lighter and has reportedly passed the most brutal tests with flying colors. Our designer is aware of the fact that his company is one of ten bidders for this particular rocket project and he also knows that his company badly needs this contract. Any one of the competitors may decide to use those new flex hoses and come out with a lighter proposal . . . So he yields to the temptation and also "optimizes" his tubing.

How did the philosopher Robert Frost put it? "There is nothing I admire more than courage—a man's capability to make a decision on the basis of inadequate evidence."

One of the least heralded but most important advances in temporary technology has certainly been in the field of metallurgy. Metals which a few decades ago were mere curiosities in the Periodic System have been entered into engineers' handbooks as respectable construction materials. Steel or aluminum processing methods and techniques had an opportunity to grow organically over a century, or at least a few decades. But how much background experience do we really have in forging, deep-drawing, welding, or heat-treating of new metals such as titanium, beryllium, or columbium and their alloys? And when we consider just two important aspects of missilery and space exploration—re-entry bodies and solid-state electronics—it becomes abundantly clear that the list of exotic materials is by no means limited to metals.

The Right Slant on Reliability

It has been our experience at the George C. Marshall Space Flight Center in Huntsville that, with the growing influx of these novel materials, the classical method of policing reliability by post-production inspection of components has become increasingly less effective. We have found it necessary to concentrate more and more on two aspects of reliability control: Critical investigation of *production methods* developed by contractors and their suppliers and *supervision of strict adherence thereto* in their actual production processes.

It may seem that we've drifted away from our original question: "What is an optimum program?" But I believe we have actually come pretty close to the very heart of it. Shall we reduce it now to the question: "How much sophistication is healthy?"*

We are living in an age of rapidly advancing technology, and it seems that even the *rate* of our technolog- (CONTINUED ON PAGE 170)

* Webster's definition for the word sophisticated: "Deprived of its original simplicity."

"Big sticks" of the Space Age

Sufficient numbers of ballistic missiles, well dispersed and mobile so as to achieve maximum survivability in case of enemy attack, and produced at minimum unit cost, represents the comprehensive deterrence this country needs in the face of the present world situation

By Maj. Gen. O. J. Ritland (USAF)

AIR FORCE BALLISTIC MISSILE DIVISION, LOS ANGELES, CALIF.

Maj. Gen. Osmond J. Ritland was assigned to the AF Ballistic Missile Div. as Vice-Commander in April 1956, and was appointed BMD Commander in April 1959. Gen. Ritland's AF career dates back almost 30 years. From 1939 to 1944, he was an AF experimental test pilot at Wright Field, flying more than 200 experimental versions of WW II aircraft. After an assignment to the China-Burma-India theater, he returned to Wright Field and, as chief of the Aircraft Laboratory, was instrumental in development of the ejection seat and pilot escape program. Gen. Ritland was assigned to the AF Special Weapons Command at Kirtland AFB in 1950 and there commanded the 4925th Test Group (Atomic), responsible for development testing of all equipment needed in attaining AF nuclear weapon capability. Then, after attending the Armed Forces Industrial College, he served for two years as Special Assistant to the AF Deputy Chief of Staff for Development before joining BMD in 1956.

THE FIRST OF JULY marked the sixth anniversary of the inception of this nation's intensive ballistic-missile program—a program established with the organization of ARDC's Ballistic Missile Division. By any standard, the progress made in these half-dozen years is little short of amazing. The ballistic-missile weapons and strategic space systems developed to various degrees of maturity during this brief period provide the U.S. with a new defense complexion, at a time when defense requirements are more important than ever before in our peacetime history.

It is axiomatic that a nation's defense structure must be tailored to international circumstances and to the state of the art in weapon technologies. The history of weaponry, of warfare, and of disarmament indicates that the nation which unilaterally relaxes in its defense posture risks its sovereignty and the security of its people.

The policy the U.S. traditionally has followed, that of limiting its military force during peacetime, is no longer practical. The dictates of time and circumstance—the advent of nuclear weapons, rapid developments in rocketry, compression of time and distance, the threat of Communism and the technical prowess evident behind the Iron Curtain—all of these factors have called for an objective and realistic appraisal of our military attitude.

It has been this sort of appraisal that has prompted the accelerated development of ballistic-missile-weapon systems. National objectives have given new meaning to the precepts of defense. Our primary concern is no longer our country's ability to reply to aggression once it has been demonstrated. Rather, we have hoped—by mounting an impressive up-to-date military force—to save the U.S. from the necessity of using that force in response to aggression. By anticipating the possibility of aggression—by facing up to the challenge squarely—we seek to preclude it. Our efforts have constituted, in truth, a paradox. Never before in history have we invested so great a proportion of our resources in weapons we hope we shall never be compelled to use. Defense as we see it today is the best practical means toward that elusive end—sustained peace with justice.

This sort of philosophy is basic to an understanding of the rationale behind our current ballistic-missile and space programs. The counsels advanced by George Washington—"to be prepared for war is one of the most effectual ways of keeping the peace"—and of

Theodore Roosevelt—"walk softly but carry a big stick"—embody truths implicit in the sum and substance of America's modern military policy. What may be viewed as a state of armed truce is more accurately the condition we call deterrence.

The weapons and strategic space systems taking shape in support of this policy are not subtle. They are, in fact, among the most costly and most ambitious of all U.S. military endeavors. They should consequently be most impressive to those whom we seek to impress. Effective deterrence cannot be expected to be subtle.

Deterrence which is to serve its intended purpose must also be positive and comprehensive, and must reflect favorably both the degrees of quality and quantity that will merit the respect of our adversaries.

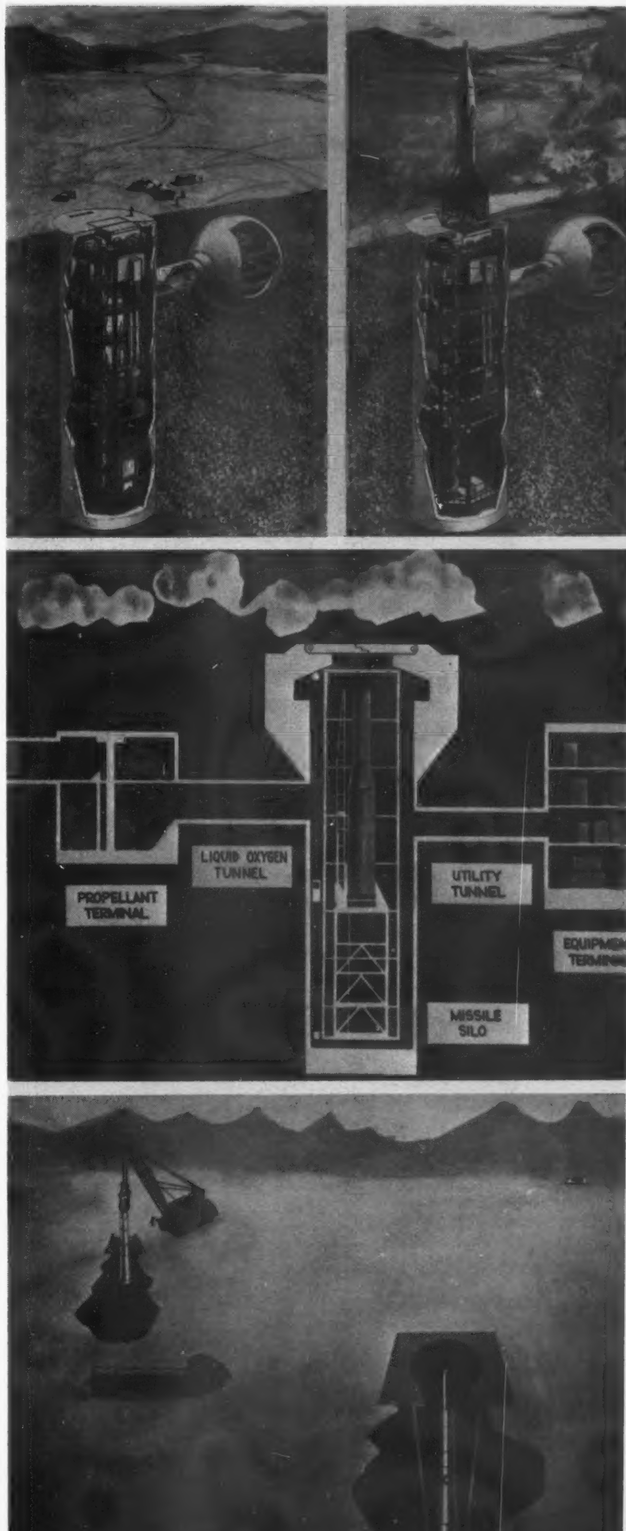
In my opinion, U.S. military and scientific developments in the last few years point straight toward fulfillment of these requirements. Our ballistic missiles, for example, represent a new kind of weapon that will influence more and more the character of this aerospace age.

The New Deterrence

In the years since World War II, our nation's growing fleet of long-range bombers, coupled with our supply of nuclear bombs, formed the backbone in our posture of absolute deterrence. The threat to this monopoly on deterrence became apparent with the harnessing of nuclear power within the Soviet Union. The threat was heightened when the Soviets began to apply their new-found capabilities in nuclear power and rocket propulsion toward ballistic missiles and aerospace weapons.

The security of the U.S. and the rest of the Free World depends on a common strength and determination to defend ourselves, to assure our security, and to support the right of every nation freely to determine its own system of government.

Back in 1954, we had (CONTINUED ON PAGE 142)



TOWARD MAXIMUM SURVIVABILITY. Top to bottom, AF Atlas, Titan, and Minuteman ICBM's emplaced in silos designed to protect the missiles against enemy attack. Steel-and-concrete Atlas silos will be built for operational Atlas squadrons 8 through 13. Early Titans will be raised to surface by elevator for launching, with later versions, using storable propellants, fired directly from the silo. Minuteman will be dispersed in quantity in hardened sites as shown, with other Minuteman missiles deployed on special-purpose trains to lend a degree of mobility to the ICBM concept.

State of the Art—1960

Astrodynamics

By Robert M. L. Baker Jr.
UCLA and AF Ballistic Missile Div.

VICE-CHAIRMAN, ARS ASTRODYNAMICS COMMITTEE

IT HAS been one of the functions of the Astrodynamics Committee of the AMERICAN ROCKET SOCIETY to mount an annual survey and analysis of the significant astrodynamic literature. Ordinarily this has been a joint effort on the part of the Chairman of the ARS Astrodynamics Committee, Samuel Herrick, and the author. This year, due to commitments involved in the XIth Annual International Astronautical Congress, Professor Herrick was forced to limit his contribution to the collection of relevant literature from the Astrodynamics Committee members. In this regard we are particularly indebted to committee members Louis Vargo, Angelo Miele, and Eugene Rabe, who have made a number of exceedingly significant contributions to the survey.

Apparently the contribution to astrodynamic literature is increasing at a very rapid rate. Each year we have witnessed about twice as many papers published as in the year preceding. Such is, of course, the trend in any burgeoning field of science. There is, unfortunately, also the general tendency to generate manuscripts without a thorough investigation of prior work. Such a tendency is particularly encouraged by the deep historical roots of astrodynamics; that is, one is almost forced to carry out a rather thorough literature survey, perhaps going back centuries, prior to embarking on research; and few of us are willing to devote the many months, if not years, of concentrated study required for this endeavor.

Although it is often difficult, tedious, and in some cases unrewarding to delve into past literature, there should be no excuse for not keeping abreast of current developments in astrodynamic research. To aid the reader in such an endeavor was to be the first purpose of the present paper; but the limits of space and the requirements for technical detail have precluded a complete exposition in *Astronautics*. It has been decided, therefore, to limit the present paper to an introduction and outline of the 1960 astrodynamics survey and to present the actual work in unabridged form as ARS Preprint 1475–60, available from the AMERICAN ROCKET SOCIETY, 500 Fifth Ave., New York, N.Y.

It is believed that 80 per cent of the astrodynamic papers published in 1960 prior to September are represented in the preprint (plus a few papers of slightly older vintage). The compiling of some 260 of these papers was a rather prodigious task and the work of the ARS Astrodynamics Committee would be greatly facilitated in the future if contributors to the field of astrodynamics would provide the author with preprints or reprints of their papers.

The second purpose of this survey, as reflected in the preprint, is to summarize and point up the advances in each of the divisions of astrodynamics. Into this latter area may creep a slight lack of impartiality, but this cannot be avoided and we do not apologize for it. As to the subdivision of the field, we have tentatively adopted the following headings: Geometry and Coordinate Systems, Astrodynamic Constants, Orbit Determination, N-Body Problem, Special Perturbations, General Perturbations, Nongravitational and Relativistic Effects, Observation Theory, Attitude Dynamics, Optimization Theory, Applications, and Education.

New Literature for the Field

The year 1960 has seen the publication of at least two monographs in astrodynamics that are general in nature and cannot be restricted to any one given division of the field. Krafft Ehricke's book "Space Flight," *Vol. 1* (D. Van Nostrand, $14.50), is an authoritative, well-written, and comprehensive treatment of astrodynamics, while "An Introduction to Astrodynamics" (Academic Press, New York $7.50) by Baker and Makemson is an introductory textbook on the subject. Although not textbooks, but still of general interest and of possible utilization in class instruction, we note the series of articles by Van de Kamp and the first portion of an article by Battin. The other volumes we have seen published this year are more in the nature of compendiums of symposium papers—e.g., "Space Trajectories" (Academic Press, New York, $12.00)—and these have chapters referenced under the appropriate subject division in the preprint.

It proves to be an impossible task to distill the 1960 astrodynamics advances to any greater concentration than has been already accomplished in ARS Preprint 1475–60. Each contribution is perhaps as important in its own way (CONTINUED ON PAGE 58)

State of the Art—1960

Communications

By Max A. Lowy, Data-Control Systems

CHAIRMAN, ARS COMMUNICATIONS COMMITTEE

THE FIELD of communications, and especially space communications, was extremely active in the past year. Successful orbiting of a number of satellites and the success of space-probe missions did much to advance the state of the art and to offer significant proof of theories relating to free space attenuation, etc.

Paddlewheel satellites such as Pioneer V proved that space communication was possible over extended distances without the use of extremely high power. Tiros I increased our knowledge of television and the transmission capabilities of TV pictures for surveillance purposes. Projects such as Echo I allowed experimentation in the passive communication satellite field and proved the practicability of utilizing a passive satellite for the transmission of radio and TV information.

Other projects, not related to space, tended to improve ground-to-ground communications, with increased interest shown in an old technique utilizing earth waves for the transmission of data from one point to another. New system techniques such as Digilock, Telebit, and extensions of Microlock, were utilized.

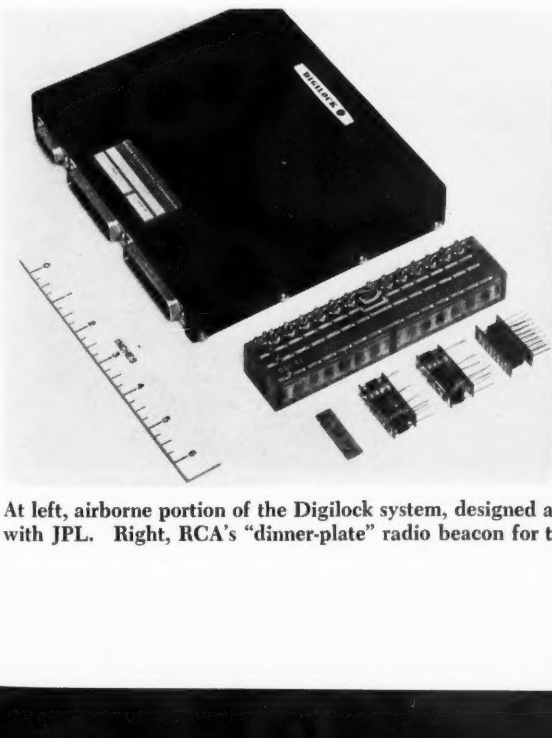
In missiles, PCM (pulse-code modulation) received a strong boost by its adoption for the Minuteman system, and a new hybrid system, PA/CM, has been evolved which combines pulse-amplitude and pulse-code techniques in a single channel. Extensions of FM techniques for telemetry in missiles have also pushed the state of the art a little bit further for general missile telemetering applications.

In other areas, Stanford Univ. obtained radar echos from the sun—an extension of last year's experiments conducted by Lincoln Laboratory in getting radar echoes from Venus. This new field of radar astronomy will probably be a useful addition to its mother science of radio astronomy.

Records in the Making

Jodrell Bank, using its 250-ft-diam antenna, received signals from Pioneer V at a distance of $27^{1}/_{2}$ million mi, setting a new record for long-range communications. Utilization of some of the newer ground antennas with more sensitive receivers to permit reception of signals from higher-power satellites will allow operation over still longer ranges. For example, a 600-ft-diam steerable reflector has been initiated at Sugar Grove, W.Va., which will be utilized for both radio astronomy and astronautics applications.

The fundamental problem in space communications (Reference 1, 8) is the ability to utilize the energy available within the vehicle to transmit the required information over (CONTINUED ON PAGE 106)



At left, airborne portion of the Digilock system, designed and fabricated by Space Electronics Corp. under a contract with JPL. Right, RCA's "dinner-plate" radio beacon for the Echo satellite.

Left, North American test pilot Al White explains X-15 mockup to some of the 900 youngsters who attended Phase I of ARS-Explorer Scout Space Science Exposition in Los Angeles. Right, Vincent S. Haneman Jr., prime mover in the ARS Youth Program along with Laurel van der Wal, discusses space guidance principles with a group of boys at Vandenberg AFB encampment.

State of the Art—1960

Education

By Irving Michelson,
Illinois Institute of Technology

CHAIRMAN, ARS EDUCATION COMMITTEE

Two and three years ago, most discussions of education in this country were dominated by suggestions as to what was wrong with the U.S. educational system. While opinions on this subject still vary, it is of particular importance now to assess what has been done to date to strengthen our educational system in order to see clearly what remains to be done.

Educational problems in this country can be divided into three distinct categories, one centering on education at the non- or pre-professional level, the second in college-level professional training, and the third on the need for significant advances in professional competence among professional scientists and engineers working on new and increasingly complex problems.

ARS has recognized its obligation to the general public by responding generously to requests for assistance on the part of interested groups and individuals concerned about education at the nonprofessional level, and it seems certain that much more of this kind of aid will be sought in the years that lie ahead. In the area of college-level professional training, too, ARS is in a unique position to furnish guidance which accurately reflects the best professional and industry viewpoints on specific curriculum and program development. The same is true with regard to the third category mentioned.

These three categories provide a convenient breakdown for discussion purposes, both in relation to the present status of education and to the portents for U.S. missile and space programs.

The most significant advance within the past year at the nonprofessional level has been the rapid acceptance of the fact that the Space Age has arrived and is no longer an uncertain and probably unrealistic dream of the future. It is interesting to note these typical developments in evidence of this situation:

1. Introduction of bills in Congress to provide direct federal support for the establishment of centers for public rocketry demonstrations and familiarization with concepts and techniques applicable to astronautical practice.

2. Public acceptance of "space" not only as an ideological competition but also as a measure of our national technological competence and as a source of direct and practical benefits affecting our daily lives.

3. Increasing requests from adult organizations seeking to learn more about astronautics from qualified professional authorities.

4. Intense interest in space flight on the part of youth, both as an area for vocational activity and as a vital element of the modern world.

It should be noted that ARS has, in one manner or another, participated and contributed importantly in each of these areas, through the individual efforts of members and also in various official statements and recommendations.

Within the Society, the major accomplishment of the year in the educational field has been the launching of an ambitious ARS national youth education program, in keeping with a directive of the ARS Board. At its meeting in November 1959 it established a policy to "encourage responsible youth organizations to undertake, (continued on page 132)

State of the Art—1960

Electrical propulsion

By David B. Langmuir, Thompson Ramo Wooldridge, Inc.

CHAIRMAN, ARS ION AND PLASMA PROPULSION COMMITTEE

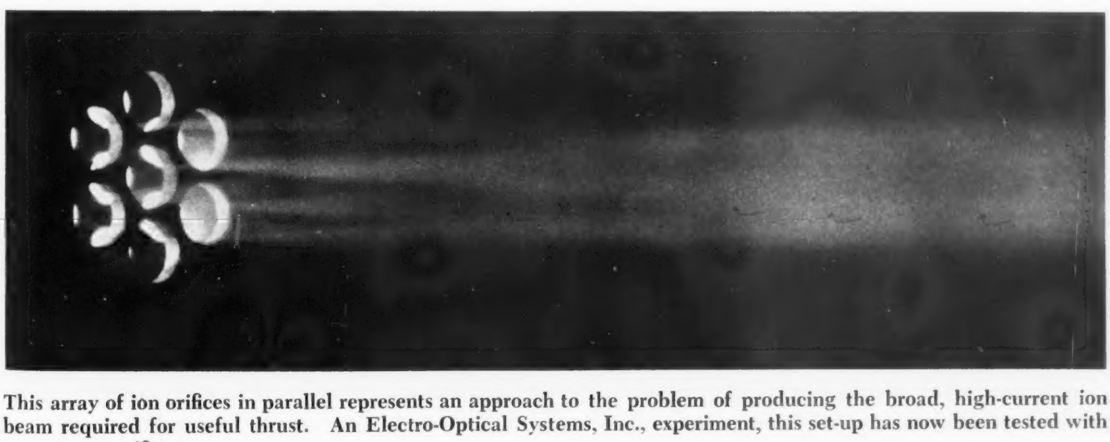
THE TECHNIQUES for using electrical energy to expel mass for thrust production fall into three rather clear categories: Electrothermal, electrostatic, and electromagnetic propulsion.

In electrothermal or arc-jet propulsion, the propellant gas is heated electrically and ejected through a nozzle in conventional fashion. The thrust is formed by integrating the pressure over the nozzle surface, and is exerted basically by the impacts of atoms or molecules on this surface. In electrostatic propulsion, or ion propulsion, acceleration is accomplished by causing charged particles to fall through a potential drop, and the thrust is exerted by intersection of lines of electric force with electrodes fixed to the engine. In electromagnetic propulsion, often called plasma propulsion, acceleration is accomplished by interaction of a magnetic field with a current through the conducting propellant gas. The thrust is exerted by interaction of the magnetic field with currents in conductors fixed to the engine.

An interesting view of the state of the art of electrical propulsion can be obtained by considering the relationship between specific impulse and efficiency for devices of these types presently being tested. In the range from a few hundred to 2000 sec, the thermal arc jet offers reasonably high efficiencies, but efficiency drops rapidly above 2000 sec. Ion propulsion devices will operate efficiently in the very high specific-impulse range, but, due to radiation losses, it will be difficult to operate the ion engine efficiently below 5000 sec. A number of devices using electromagnetic fields to accelerate a plasma have been proposed to fill the gap between 2000 and 5000 sec, but as yet none of these show efficiency above 10 per cent. These electromagnetic devices have been tested at specific impulses of 10,000 sec and above and therefore also overlap with ion propulsion in the high-specific-impulse range. Two review papers of the state of the art of electrical propulsion have recently been published (References 1 and 2).

Potential of the Arc Jet

Electrothermal or arc-heated systems make use of an electric arc which burns in a chamber into which the propellant gas is fed (3). The temperature within the arc may be as high as 50,000 K, while the average temper- (CONTINUED ON PAGE 90)



This array of ion orifices in parallel represents an approach to the problem of producing the broad, high-current ion beam required for useful thrust. An Electro-Optical Systems, Inc., experiment, this set-up has now been tested with many more orifices.

State of the Art—1960

Guidance and navigation

By James S. Farrior
LOCKHEED MISSILES AND SPACE DIV.
CHAIRMAN, ARS GUIDANCE AND NAVIGATION COMMITTEE

WHEN development was first seriously begun on ballistic missiles in this country a little over a decade ago, it was believed by many people that some form of radio guidance was probably the only way the required accuracy could be obtained. Radio guidance also offered the possibility of a simpler missile, although at the expense of more complex ground equipment. Some believed that the accuracy could only be achieved through a radio-inertial system which would use relatively low quality inertial equipment to enhance the accuracy of the radio system.

This lack of general acceptance of all-inertial systems was due to a number of different influences. World War II and the Korean War had resulted in the development of a large amount of electronic equipment, including radars of many kinds. As a result, many well-trained electronic engineers were to be found among those making up the new missile industry. These were augmented by hordes of recently graduated engineers who had majored in electronics or electrical engineering. The vast electronics industry, anxious to participate in this new field, worked hard at trying to sell systems which they knew how to design and build or believed they could develop. Error analyses showed that although the specifications were tough, radio systems could probably meet the requirements.

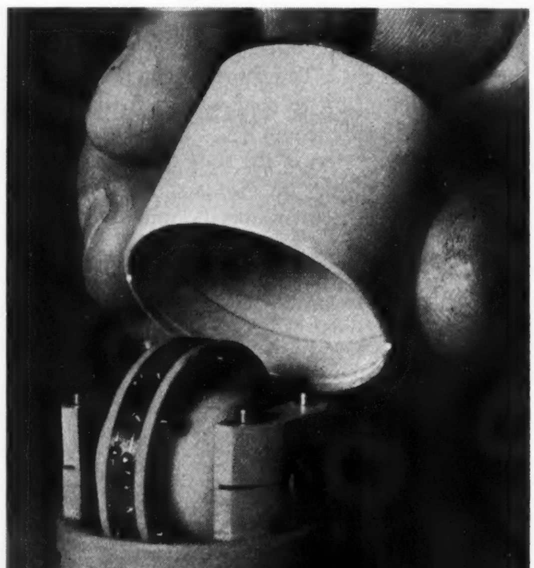
Inertial Guidance—A Success Story

On the other hand, there was a comparatively small number of engineers having the proper training and experience to evaluate the possibility of using inertial guidance. Even engineers who had had experience with precision mechanical devices were appalled at the accuracies required and were sometimes discouraged to the point of believing them to be unobtainable by reasonable means, if at all. Furthermore, there is just something uncanny and a little unbelievable to the uninitiated about a guidance system which has no contact with the outside world, yet guides the vehicle so as to cause impact at a chosen target.

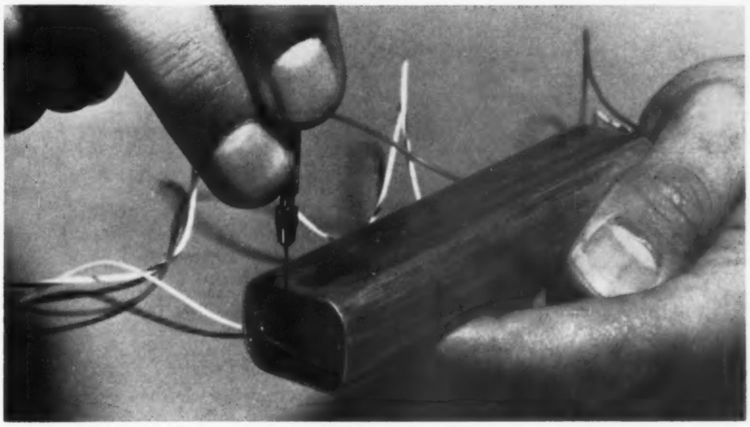
Although the basic principles on which to base the design of inertial instruments were known, it was obvious that much development was required before inertial components of acceptable accuracy would be available. Then there was the problem of the computer. At that time, digital computers were too large to be considered, and any experienced analog-computer designer could tell you how hard it would be to get within an order of magnitude of the desired accuracy with equipment which could be flown in a missile. In short, anybody trying to sell an inertial-guidance system for a ballistic missile had a hard row to hoe.

In spite of the skepticism, enough people were convinced that inertial systems, if they could be made to work, offered some rather obvious advantages; and although they were often backed up by other types of systems, development was allowed to proceed.

The ensuing years have seen the successful development of a number of inertial systems. Relentless efforts on the part of designers and manufacturers, as well as a lot (CONTINUED ON PAGE 150)



Minneapolis-Honeywell's miniature gyro with gas-spin-axis bearing, making use of precision ceramics, was one of the year's most interesting component developments.



Thin slice of silicon forms tip of radiation detector developed by Hughes Aircraft for AF to measure radiation man will meet in space. AF School of Aviation Medicine will launch the detectors, packaged with signal amplification units in cigar-size containers, in simulated space cabins of high-altitude balloons and in Atlas nose cones.

State of the Art—1960

Human factors and bioastronautics

By Lt. Col. Stanley C. White (USAF-MC), NASA Langley Research Center

CHAIRMAN, ARS HUMAN FACTORS AND BIOASTRONAUTICS COMMITTEE

THE REPORT in last November's *Astronautics* by the ARS Human Factors and Bioastronautics Committee closed with a plea for an integrated approach by the human factors community and allied professional groups in their efforts to keep pace with the rapidly accelerating U.S. space program. It is heartening to be able to report this year that this integrated approach is now taking shape, as evidenced by establishment of a Life Sciences Directorate within NASA Headquarters and steps taken toward U.S. participation in an integrated life sciences program in the International Astronautical Federation.

Accomplishments during the past year in the human factors and bioastronautics aspects of astronautics have been many and varied, and marked by outstanding U.S. and Soviet successes. In addition to the successful Russian orbital flight and recovery experiments involving biological organisms, remarkable progress has been made in this country in a number of different areas.

For example, flight worthiness of the physiological data system developed for the X-15 has been proven in test flights, and the establishment of new speed and altitude records by test pilots Joe Walker of NASA and AF Maj. Bob White, respectively, reflect successful integration of the engineering and biological sciences, each of which has long worked toward these goals.

Certainly the outstanding achievements of AF Capt. Joe Kittinger in high-altitude escape experiments are worthy of mention, since they have provided future airmen with a method for successfully leaving a vehicle even at space-equivalent altitudes.

Progress in bio-instrumentation in the past year has been remarkable, having reached the point where aircrew members can continue to perform flight tasks while studies of body physiology go on under actual working conditions.

Meanwhile, disorientation studies, under way at the Navy School of Aviation Medicine and elsewhere, point the way toward solution of this important problem.

A Surge in Bio-Space Technology

Obviously, this brief list is incomplete and merely touches on a few high points. A list of this kind could grow to remarkable length, with each laboratory, each company, and each project demonstrating not only that progress is being made in bio-space technology, but that it is coming at an ever-increasing rate.

Thus it appears that the biological community is responding to the challenge of the engineering schedule for manned space (CONTINUED ON PAGE 98)

State of the Art—1960

Hypersonics

By Richard D. Linnell, Southern Methodist University

VICE-CHAIRMAN, ARS HYPERSONICS COMMITTEE

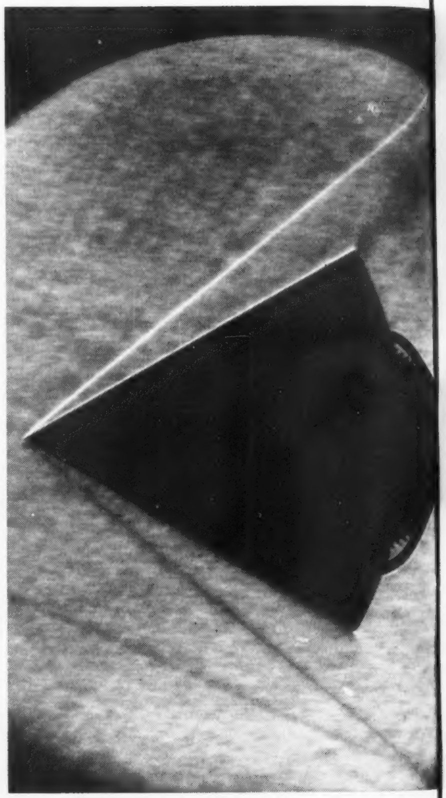
Hypersonics has been described (Reference 1) as "high Mach number aerodynamics." It is an important part of the art and science of astronautics. That hypersonic theory can provide working designs for space vehicles is already a well-established fact. But much remains to be done in hypersonic theory, laboratory experiment, and flight test to provide a firm basis for design, development, and improvement of vehicles. Significant progress toward this goal was made in hypersonics during 1960.

The ARS summer meeting in Los Angeles in May featured three well-attended sessions on hypersonics—indicative of the great interest in, and work on, hypersonics at present. The problems are new, difficult, and quite varied. The following discussion will consider the properties of gases, as needed in hypersonics, inviscid flow, viscous flow, and magnetohydrodynamic hypersonics.

Knowledge of the properties of gases is required in considerable detail for hypersonic aerodynamics. Statistical mechanical and experimental studies of the composition, thermodynamic properties, and transport properties (2, 3) of moderately high-temperature gases continue. The thermodynamic (4) and electrical (5) properties of equilibrium high-temperature gases were studied by several groups.

The chemical kinetics of nonequilibrium gases received considerable attention, but the state of the art is still far from satisfactory from the viewpoint of hypersonics. Methods for estimation of the flight regimes wherein nonequilibrium effects may be important were presented (6), but quantitative estimates depend on the values used for the chemical kinetic parameters which are still uncertain. Experiments (5, 7), designed to check the flow conditions at which nonequilibrium effects appear, help define chemical kinetic parameters. However, an adequate theoretical model for the chemical kinetics is needed. A survey of recent advances in the chemical kinetics of homogeneous reactions in dissociated air was published (8) early in 1960.

Inviscid hypersonic flow received considerable attention during the year. Solutions for oblique shock for air in equilibrium were obtained (9) and checked experimentally. Additional approximate solutions for cones in axial flow (10, 11), yawed cones (12), and blunt bodies (13–15) in an equilibrium gas were published. Experimental results for blunt noses and blunt bodies were presented (16). Further study (17) of the nature of the mathematical and physical approximations involved in the assumptions which provide the basis of Newtonian theory (CONTINUED ON PAGE 116)



Schlieren photo of adjustable wedge at 30 deg and 30-deg angle from centerline. (Reference 9)

State of the Art—1960

Instrumentation and control

By John E. Witherspoon, Rocketdyne Div. of North American Aviation

CHAIRMAN, ARS INSTRUMENTATION AND CONTROL COMMITTEE

THE YEAR which has seen contracts let for the development of new very large cryogenic liquid-propellant booster rockets, large storable liquid-propellant engines, and cryogenic propellant upper-stage engines; feasibility studies of very large solid-propellant engines, segmented grain motors and high-energy storable propellants; a new series of nozzles, and more work in electrical propulsion and space power systems has also seen a continued effort to increase measurement accuracy, speed in data reduction, and the capability of making laboratory-level type measurements under field-test conditions. More work has also been done to make the rocket engine a controllable system which will result eventually in automatic landings and space taxis and tugs.

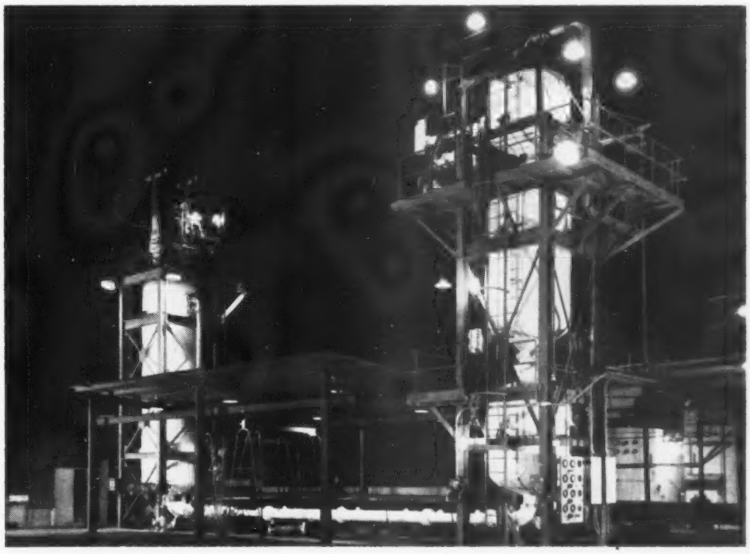
In some cases, the instrumentation and control advances are directly applicable to the rocket systems; in others, there is an indirect support.

Sensing elements, sensors, or transducers are perhaps the greatest problem of the instrument engineer, since electronic and data reduction equipment and techniques cannot improve on the output information they supply.

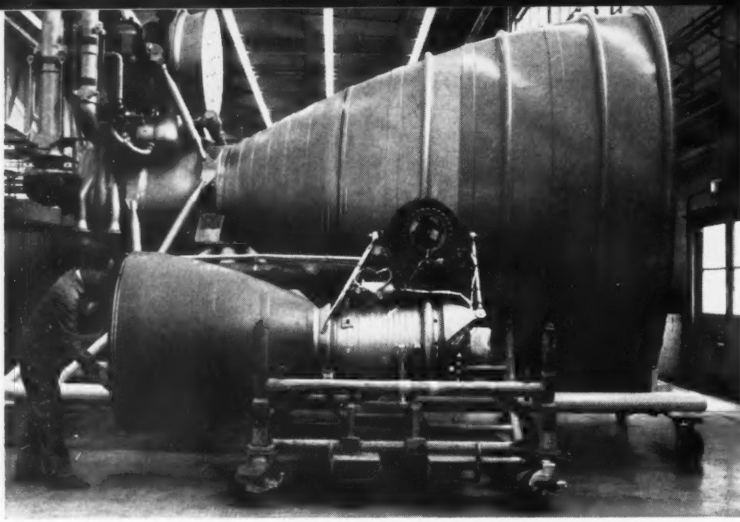
Refractory-Metal Thermocouple Ready

Now, after years of work, the refractory-metal thermocouple has been developed to the point where it can be used in engine testing. Such combinations as tungsten and tungsten-rhodium, tungsten and tantalum, iridium and iridium-rhodium, tungsten and molybdenum, and tantalum and molybdenum have been made available for use in the range of 4000-5500 F. While some of these combinations are plagued by low output potentials or thermal-emf slope reversals with temperature, others have outputs higher than 5 microvolts per degree F. These latter are now included in the encyclopedia of standard thermometry.

The extensive work on mass flow measurement over the past 10 years has (CONTINUED ON PAGE 154)



Aerojet-General cryogenic flow facility, capable of calibrating flowmeters in liquid oxygen at rates up to 1200 lb/sec. The proved tank accuracy is 0.028 per cent.



Rocketdyne H-1 Saturn engine (foreground) is dwarfed by full-scale mockup of the F-1 million and a half-pound-thrust liquid engine which the same company is developing for NASA.

State of the Art—1960

Liquid rockets

By Martin Goldsmith, The Rand Corp.

CHAIRMAN, ARS LIQUID ROCKETS COMMITTEE

THE PAST calendar year might well be described as a period of fruition for the U.S. space flight program. After the initial shock of the Sputnik I launching, our citizens, beset by frustration and disappointment, could be comforted only by the assurances of some knowledgeable persons that our own space technology was of considerable breadth and depth, albeit tardy. While a measure of doubt continued in the minds of some, the events of the past months have indeed shown that our own abilities are not inconsiderable.

Owing to the great importance of liquid-propellant rockets to our space program, it is significant that in this particular area also the past year can be described as a time of fruition. Many improvements in technology, labored at over the years, have appeared in full bloom. To illustrate this claim, some excerpts have been drawn from the column, "For the Record," that appears monthly in *Astronautics*. (Selected from the period from Sept. 1, 1959 to Aug. 31, 1960.)

Sept. 1—Air Force reveals it successfully test-fired the XLR-99-RM-1 X-15 rocket engine.

Dec. 6—Pratt and Whitney reports successful test-firings of XLR-115 liquid-hydrogen engine to be used for Project Centaur.

Jan. 27—Lockheed unveils Agena engine that can be restarted in space to change the orbit of a satellite.

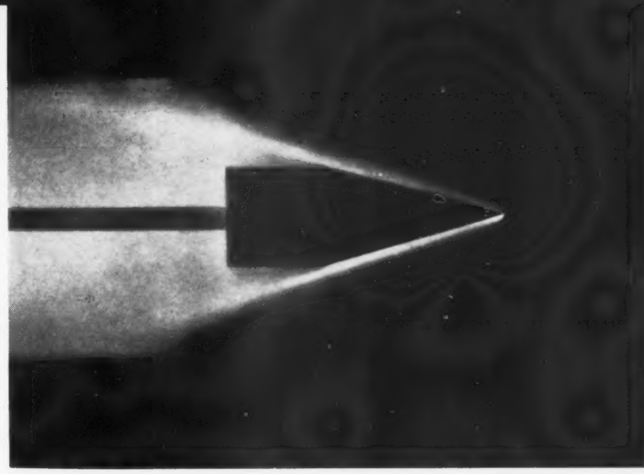
Feb. 2—Titan second stage separates successfully under command guidance in 2000-mile AF flight test.

April 13—Navy launches Transit 1-B navigational satellite, weighing 265 lb, into orbit; marks first time a rocket engine has been restarted in space.

April 29—Saturn produces 1,300,000-lb thrust in first NASA test firing of all eight first-stage rocket engines.

Certain other significant announcements, while omitted from the column, are also worthy of note. Storable liquid propellants are to be used in Titan II, Rocketdyne fires F-1 engine thrust chamber at over 1,000,000-lb thrust, NASA announces that Rocketdyne is chosen to develop 200,000-lb thrust hydrogen-oxygen engine for Saturn.

These events have done much to dispel the doubts and reservations that have surrounded the use of liquid-propellant rockets in earlier years. For example, while it has long been recognized that the use of liquid hydrogen as a fuel offered great advantages in vehicle performance, serious doubts existed as to our ability to successfully utilize this bulky and highly cryogenic substance. However, the success of the rocket industry in developing components for hydrogen engines (Reference 1) and subsequent success in developing complete engine systems, represented in part by the Pratt and Whitney Centaur unit (2) insure that our space program will (CONTINUED ON PAGE 169)



Time-integrated picture of flow luminosity around 15-deg wedge in nitrogen in Lockheed electromagnetic shock tube. Incident velocity of nitrogen = 10 cm per microsecond, initial pressure = 50 μ (Ref. 5).

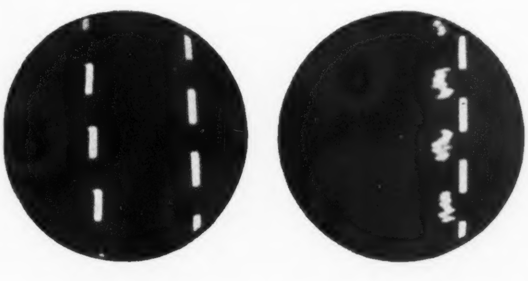
State of the Art—1960

Magnetohydro-dynamics

By Ali Bulent Cambel, Northwestern Univ.

CHAIRMAN, ARS MHD COMMITTEE

During the past year, and since the last annual summary by Milton Clauser (Reference 1) magnetohydrodynamics has continued to be a subject of vital interest to pure and applied scientists. The intellectual virility which MHD enjoys is due to the fact that it is a most versatile field. Not only does it continue to challenge its earliest discoverer, the astrophysicist, but it also offers innumerable opportunities to the aerodynamicist concerned with re-entry, the propulsion engineer eager to develop new propulsion devices, the mechanical engineer, and the physicist on the threshold of designing commercially practical fusion power and propulsion devices. The electrical engineer is interested in it because he wants to develop new homing and detection devices. The experimentalist is fascinated by it because there are numerous experiments he might conduct to produce much needed data, while the applied mathematician finds in MHD a veritable storehouse of fascinating problems he might solve. One might indeed characterize MHD as a renaissance science.



Left, amplitude of microwave signal transmitted through test section with no plasma flow. Right, amplitude of signal passed through argon plasma in Northwestern Gas Dynamics Lab plasma facility. Modulated microwave signal = 9.11 kmc, scope sweep frequency = 90 cps (Ref. 15).

Presenting the developments in such a vast and rapidly growing subject is beyond the scope of any one man, and it is also impossible to summarize all of its aspects in a short survey paper such as this. An attempt will be made, however, to touch upon the highlights. Admittedly, this will demonstrate the ignorance and the prejudices of the author.

To commence, a word or two about the name of this prodigal son is in order. Many have been suggested, such as magnetohydrodynamics, magnetoaerodynamics, magnetogasdynamics and a host of others. At the 1959 Evanston meeting Theodore von Karman made a personal plea to name it "magneto-fluid-mechanics." Undoubtedly, this is a descriptive and general name that should embrace almost all varieties of the subject. Whether it will remain MHD or become MFM remains to be seen, however, because names have a peculiar way of catching on.

Compilations of the numerous publications may be found in References 2 and 3.

The fundamental equations of magnetohydrodynamics are a combination of the non-linear Navier-Stokes equations so well known to the fluid-mechanician and the linear Maxwell equations, commonplace in electromagnetism. The equations of MHD thus remain non-linear in form, and there is no general solution to them. Thus, they must be solved for specific cases. Eugene Covert (4) has summarized the situation very succinctly by stating: ". . . in several publications the MHD results are presented in fractional changes from fluid mechanics. In some cases this step can provide an estimate of the MHD effects without a complete solution to the Navier-Stokes equations. The Navier-Stokes equations in most cases (CONTINUED ON PAGE 124)

State of the Art—1960

Missiles and space vehicles

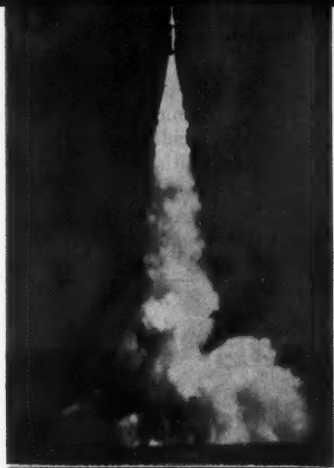
By Maxwell W. Hunter, Douglas Aircraft Co.

CHAIRMAN, ARS MISSILES AND SPACE VEHICLES COMMITTEE

During the past year, continuing progress in missile and space-vehicle design has been achieved. In actual accomplishments the space-vehicle field was highlighted by a list of successful launches now become so long that some of the novelty is starting to disappear from these events. The Pioneer V deep-space probe, which was launched so as to come close to the orbit of Venus, recorded the farthest communication transmissions achieved to date. The last signal received from the satellite traveled a distance of over 24,000,000 mi. Explorer VI was launched into a highly eccentric orbit and has transmitted much useful data on the radiation intensities of the inner and outer extremities of the radiation belts. Two launches of Transit navigation satellites were successful, and in the second firing an additional satellite package was carried, making this the first piggyback satellite launch in history. A number of Discoverers were launched into polar orbits, and the first successful de-orbit, re-entry, and recovery from space occurred when the Discoverer XIII capsule was retrieved from the ocean. This truly historic event was followed almost immediately by the successful air-pickup at an altitude of 8500 ft of the Discoverer XIV capsule. Such a demonstration clearly indicated the feasibility of each phase of recovery and opened the door for many new space experiments. The Tiros meteorological satellite, at the time of its launch, was placed on one of the most nearly precise circular orbits achieved. It returned well over 20,000 cloud-cover photographs before ceasing operations. Echo I balloon satellite, placed on the highest nearly circular orbit achieved to date (approximately 1000 mi), is being used for many communication experiments.

Progress in Launches

All of the aforementioned launches made use of the Thor IRBM as a first stage, although a variety of upper stages were used. A new upper stage, Aerojet's Able-Star, was successfully used on the Transit launchings. Precise radio guidance was used for the first time in the Tiros launching and in the subsequent Delta-Echo I operation. An Atlas-Agena combination successfully launched the first experimental Midas early warning satellite. It is gratifying to note that the percentage of successful launches to total tries has improved markedly over the previous years. (CONTINUED ON PAGE 64)



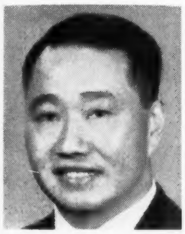
Recent major advances: Top, launching of Polaris from a submerged submarine in anticipation of operational status for the missile late this year; middle, a Discoverer launch with Thor-Agena, such as returned the capsules of XIII and XIV from orbit; and, bottom, unveiling of the Dynasoar design approach and notice by the Air Force that it will place new emphasis on the manned boost-glide vehicle.

State of the Art—1960

Nuclear propulsion

By C. J. Wang, Space Technology Laboratories, Inc.

CHAIRMAN, ARS NUCLEAR PROPULSION COMMITTEE



A SUCCESSFUL nuclear-propulsion development requires studies designed to determine the most suitable missions in order to explore the full potential of nuclear propulsion and efforts planned to learn the necessary techniques leading to successful development of various nuclear-propulsion systems. Mission studies have been and are still being actively performed by various organizations in the country. Research and development efforts are being vigorously maintained by the military services, AEC, and NASA in the areas of turbojet, ramjet, rockets, and power supply. This article surveys the status of the various nuclear-propulsion activities existing in this country.

Turbojet Development

The turbojet development is known as the Aircraft Nuclear Propulsion (ANP) Project. Its objective is to develop a turbojet engine which utilizes a fission reactor as a source of energy instead of the conventional chemical combustion chamber. It is reasonable to hope that this type of engine will eventually provide capabilities characteristic of a turbojet but uniquely suitable for missions requiring extremely long flight without refueling.

The present project has adopted the dual approach of developing both a direct-cycle and an indirect-cycle propulsion system. In a direct cycle, the air is forced through the core of a reactor to receive heat for producing thrust. In an indirect cycle, the reactor energy is carried in a closed circuit to a heat exchanger where it will heat up the air for producing thrust.

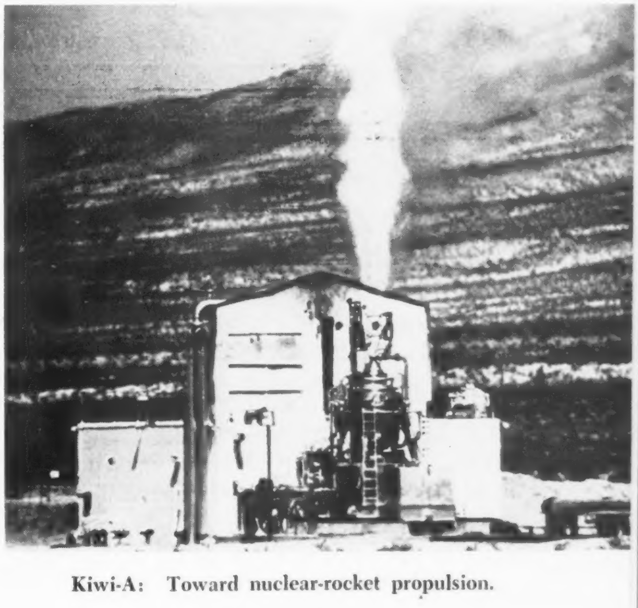
Recent work on a reactor for the direct cycle has progressed to a level where a test reactor can be operated at a core temperature higher than 1500 F. Extensive testing is now underway on advanced reactor design for operations at considerably higher temperatures, which are necessary for the achievement of worthwhile performance. The indirect-cycle development has a somewhat younger history, but important progress has been made in establishing the compatibilty of a high-temperature solid-fuel element and a liquid-metal coolant. Progress is also being made toward a definite reactor design for the engineering experiment.

In the area of propulsion-system components other than the reactor, the development effort is continually producing results. Specific turbojet engines, designed for a nuclear-reactor heat source, have been developed and tested. Advanced designs are presently in development for adaptation to the advanced reactors. A control system suitable for all modes of nuclear-turbojet operation has been designed and has been successfully tested. A significant amount of radiation shielding data has been collected by various methods, including a series of B-36 flights carrying a small reactor. These data will be very valuable in designing aircraft subsystems.

Program Is Quite Active

The over-all ANP program is currently maintained on quite an active level. Indications are that within several years the state of the art will be advanced to a point where a nuclear turbojet aircraft could be built with a capacity of performing unique military as well as non-military missions in the supersonic and high-subsonic regions.

The project known as Pluto, centered at the Lawrence Radiation Laboratory, is devoted to the research and development (CONTINUED ON PAGE 168)



Kiwi-A: Toward nuclear-rocket propulsion.

NRL X-ray photograph of the sun, obtained from Aerobee-Hi launched from White Sands April 19, 1960. The photo clearly shows the phenomenon of limb brightening and intense local sources in regions of high solar activity corresponding to visible plages.

State of the Art—1960

Physics of the atmosphere and space

By Herbert Friedman, U.S. Naval Research Laboratory

CHAIRMAN, ARS PHYSICS OF THE ATMOSPHERE AND SPACE COMMITTEE

SUBSTANTIAL advances in our knowledge of atmospheric and space physics have been achieved with the aid of vertical probes, satellites, and ground-based instrumentation. The following resumés represent only a small sampling of the valuable store of scientific observations reported on during the past year.

In the area of solar spectroscopy, a photoelectric recording spectrograph, designed and flown by AFCRC in Aerobee-Hi rockets, has provided data on solar-emission lines reaching to wavelengths in the X-ray range. Of special importance are the observations of the intensity of the resonance line of singly ionized helium (304 Å). This line contains most of the electromagnetic energy effective in ionizing and heating the F-region of the ionosphere. Similar studies by photographic means at the Univ. of Colorado also indicate a predominance of this particular radiation. At longer wavelengths, NRL has succeeded in further refining the photographed spectrum to the extent that more accurate data are available on continuum intensities, and evidence has been obtained for the atmospheric content of molecular nitrogen, which appears to reach an optical depth of unity slightly above 220 km.

Experiments conducted by NRL in 1959 produced high quality images of the sun in Lyman-α. Further progress in solar disk photography was made in 1960 with the production of the first image of the sun in its X-ray emission, shown above. The photo was made with a pinhole camera mounted on a biaxial-pointing control and carried to 130 mi by an Aerobee-Hi. Clearly evident in the picture is the phenomenon of limb brightening and the existence of intense local sources in regions of high solar activity corresponding to the visible plages.

Theories on Interplanetary Space

With regard to density of the interplanetary medium, on the basis of observations of the night sky luminescence at the wavelength of Lyman-α (1216 Å), various theories have been developed that account for the phenomenon in terms of resonance scattering by neutral hydrogen in the interplanetary medium or in a geocorona. NRL has continued its experimental studies of this phenomena in two ways. High-resolution spectrograms of the solar Lyman-α line have shown a deep, narrow self-reversal which may be attributable to geocoronal hydrogen at a temperature of 800–2100 K with 3×10^{12} atoms per sq cm column above 100 km. The observations seem to indicate the possibility of a 50-per cent change in total overhead neutral hydrogen between 100 and 200 km. A second type of experiment is the measurement of the change in overhead brightness of the night sky with increasing altitude. If the hydrogen is local, overhead brightness should decrease with altitude according to the distribution of the hydrogen with altitude. An experiment performed with a Javelin rocket which carried the instrumentation to a height of 1400 km was inconclusive. The scale height of the hydrogen was so great that a flight to at least one earth radius is necessary to resolve the question.

In the field of rocket astronomy, further studies of the ultraviolet emis- (CONTINUED ON PAGE 128)

State of the Art—1960

Power systems

By A. M. Zarem, Electro-Optical Systems, Inc.

CHAIRMAN, ARS POWER SYSTEMS COMMITTEE

IN THE past year, space power systems have been recognized as requiring intensified research and development effort if planned space missions are to be successful. The Air Force, for example, has increased research funding in this technical area sixteen-fold in the past three years. Planned expenditures by ARDC should peak at about $200 million in 1967. The term "secondary" or "auxiliary" power is now a misnomer and has, in general, been dropped from government terminology, and the term "flight vehicle power" is used instead.

Extensive research is essential to attain mission capability in satellite, lunar, and planetary vehicles. Future power requirements will rise almost exponentially. While current vehicles require less than 100 watts, by 1965 long-duration power systems of 10- to 15-kw output are planned, rising to the order of 50 kw by 1970 (Reference 12). If ion or plasma propulsion is used, the power requirements may be 100 kw by 1965 and megawatts by 1970.

Actual electrical load requirements for advanced vehicles will probably consist of a series of short, relatively high-power-level drains superimposed on a steady-state low-level load. Planned vehicle missions are quite diversified, and the design of a power system will necessarily be specifically tailored to the payload. All three major types of power systems—i.e., chemical, solar, and nuclear—will be used in a number of variations.

Because of low fixed weight and relatively high-conversion efficiency, chemical systems will continue to provide weight advantages in orbital and space vehicles where total energy requirements are relatively low. At high power levels or longer durations, chemical-fuel weight becomes prohibitively large and systems based on solar- or nuclear-energy sources must be used. These systems are generally characterized by a high fixed weight. This point is illustrated in the chart on page 102, which displays approximate power-duration regions where specific systems, using predicted 1970 component performance characteristics, appear to offer minimum weight (6). These zones illustrate the necessity for broad investigation into many types of power sources. It should be noted that the zone boundaries vary significantly depending on the specific mission.

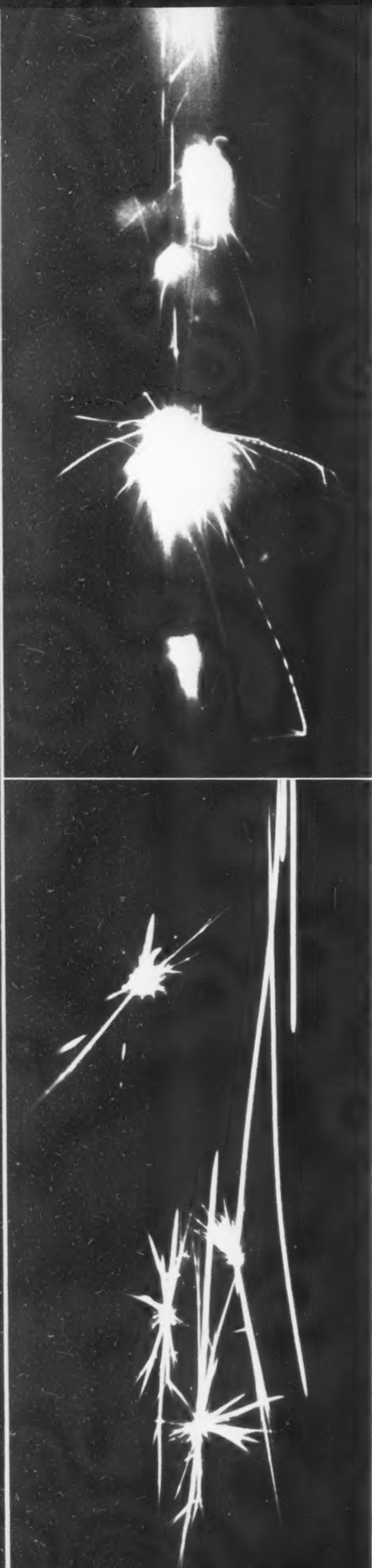
System weight cannot be used as a single figure of merit; however, weight estimates are amenable to mathematical analysis and systems are popularly rated by a specific weight figure (lb/kw). Reliability (particularly in a manned vehicle) is generally the first requirement to be satisfied. Other design criteria may become more important in any specific design, including items such as packagability, radiological or other hazards, vehicle thermal balance, orientation requirements, and cost.

Competition Among Chemical Systems

Two chemical systems under development which are competitive in durations of hours to days are the hydrox primary fuel cell and the positive-displacement engine operating on an Otto cycle, both of which use stored hydrogen and oxygen. Weights of 1 to $1^1/_2$ lb/kw-hr for durations greater than 10 hr appear possible in the 1965–70 period. Further improvements in the operational properties of hydrogen and oxygen cells have been made in the past year.

Union Carbide has pushed the development of its hydrogen-oxygen cell (with catalyst-impregnated carbon electrodes) to the (CONTINUED ON PAGE 102)

Small experimental solid-skin mirror developed by Electro-Optical Systems for studies of advanced solar thermal systems to operate at temperatures around 2000 F. Such mirrors, which must be both accurate and light, represent a current engineering challenge.



State of the Art—1960

Propellants and combustion

By Peter L. Nichols Jr., Stanford Research Institute

CHAIRMAN, ARS PROPELLANTS AND COMBUSTION COMMITTEE

EARLY successes in submarine launchings of the Polaris missile have again focused attention on the potentialities of large solid-rocket engines. At the same time, the liquid-engine field is moving ahead, with attention directed toward storable propellant systems such as N_2O_4 and UDMH-hydrazine. There has also been a mild rejuvenation of interest in liquid monopropellants. The never-ending quest for high-energy propellants has created renewed activity in hybrid-propellant systems and exotic combinations of materials which in principle at least might be fabricated into high-energy solid propellants by encapsulation techniques. In all these areas of propellant development, combustion problems abound and in many cases will be the critical consideration in the selection of a propellant system.

The trend toward high-energy propellants is strongly affecting the nature of propellant R&D programs. Fundamental in this respect is the establishment of a sound and effective thermochemical program. Largely as a result of the ARPA program, much additional effort is being directed toward the establishment of reliable thermochemical data. The large program at the National Bureau of Standards under the direction of Charles Beckett is a welcome addition to the propellant program, and useful compilations of data have already been forthcoming. Many university groups have also directed their efforts toward obtaining thermochemical data of interest to the propellant field. Particularly noteworthy contributions have been made by Charles Margrave et al. at the Univ. of Wisconsin, relating to thermochemistry of the light metals.

Other problem areas of special importance in high-energy propellant development are: (1) The transition from deflagration to detonation; (2) unstable combustion; (3) shock and thermal sensitivity; and (4) aging or storage stability. Much work is being conducted on deflagration-detonation transition. However, there have been no outstanding contributions in this field reported recently in the open literature. The areas of shock and thermal sensitivity have not received significant contributions. A useful contribution to the closely related subject of ignition has been made, however, by using a shock-tube technique (CONTINUED ON PAGE 60)

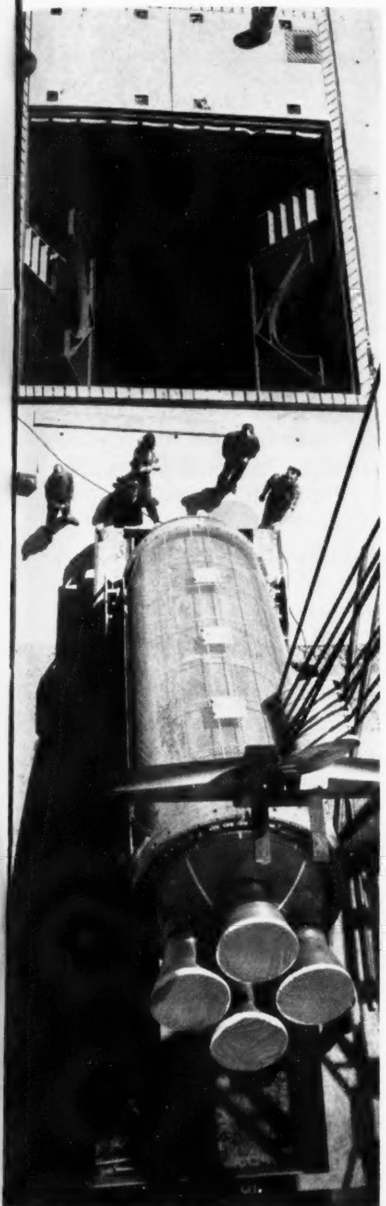
These photos, taken by Derck Gordon of Stanford Research Institute, show the interesting fragmentation effects obtained when titanium (above left) and magnesium-aluminum alloy (below left) are burned in an oxygen-rich gas stream.

State of the Art—1960

Solid rockets

By G. Daniel Brewer, Grand Central Rocket Co.

CHAIRMAN, ARS SOLID ROCKETS COMMITTEE



The giant booster for Minuteman, the first U.S. all-solid ICBM, comes out of the casting pit, loaded and cured, at Thiokol's Utah Div. Minuteman is scheduled for its initial flight test under full first-stage propulsion late this fall.

THIS annual State-of-the-Art issue of *Astronautics* offers the opportunity of lifting one's head above the daily routine of business and assessing the position of his segment of the propulsion industry relative to the others. Where do solid-propellant rocket motors stand in terms of performance, reliability, acceptance, and usefulness in relation to other possible systems which might be used instead?

The propulsion system with which solids are most frequently compared when a missile-system designer chooses a powerplant for a new missile is one using liquid propellants. Until 1956–57, when the Minuteman and Polaris missiles were designed, there was very little serious consideration given to the possibility of using solid-propellant rocket motors in long-range missiles. The Army Sergeant missile was the largest and longest-range solid-propellant missile then contemplated. The significantly higher specific impulse and the very low cost per pound of the liquid propellants were overwhelming arguments in the minds of those responsible for choice of propulsion systems for the missiles prior to that time. When really serious consideration was given to the possibility of using solid propellants in intermediate- and intercontinental-range ballistic missiles, and a study was made of the comparative logistic problems, the picture began to change.

Instant Readiness Important

The concept of "the advantage of high specific impulse" was shown to be of secondary importance. It came to be realized that system cost, reliability, and simplicity of operation (usefulness) were the really important parameters. For military applications, the feature of instant readiness was also recognized as an important consideration.

In missile-system applications the prime consideration is the maximum payload weight which can be delivered to the target per dollar spent for the delivery system. The phrase "delivered to the target," of course, includes consideration of those missiles which may have been launched, or were scheduled to be launched but failed to reach the target for some reason, such as system failure or enemy action. The number of dollars spent for the delivery system, when considered in this light, has been shown to be virtually independent of the cost per pound of the liquid pro- (CONTINUED ON PAGE 164)

State of the Art—1960

Space law and sociology

By Andrew G. Haley, Haley, Wollenberg, and Bader

CHAIRMAN, ARS SPACE LAW AND SOCIOLOGY COMMITTEE

In last year's state-of-the-art report on Space Law and Sociology, considerable emphasis was placed on the importance of the social sciences in the Space Age and to the foresight and wisdom of ARS leaders in providing recognition and a forum for social sciences within its organization.

Before discussing substantive problems and achievements of the past year, some statistical achievements should be noted. For example, it was the Space Law and Sociology Committee which held the first ARS Specialist Conference, on March 20, 1959, in New York City. The Conference marked another important "first," since, insofar as can be ascertained, it was the first occasion on which an official subcommittee of the House Committee on Science and Astronautics was named to participate in a meeting sponsored by a nongovernmental organization.

Interest in Subject Is Broadening

Since that date, the Committee has participated in a number of national meetings of the Society, and ARS members have been privileged to hear the views of U.S. senators and congressmen and outstanding lawyers, sociologists, and statesmen from the U.S. and abroad at these meetings.

In the past year, outstanding technical and scientific achievements in space have vastly complicated the legal, social, and political aspects of the new Space Age. Witness the Courier delayed repeater communications satellite and the legal regulatory complications which will result; the dangers inherent to public and private property in the Discoverer capsule launchings; the implications of the Echo satellite, which will eventually require the worldwide solution of problems in radio regulation heretofore unsolvable domestically; the dangerous implications from the standpoint of international relations of the Midas program, and the equally touchy legal aspects of the Samos program; and the problems created by Tiros and its successor picture-taking weather satellites.

The problems posed by such programs are many and varied. Their scope can perhaps best be visualized by the rundown on the Working Groups of the IAF International Institute of Space Law which follows. The ARS Committee on Space Law and Sociology cooperated with members of the Institute in drafting assignments for these Working Groups.

These "terms of reference" tell the story of the tasks which still lie ahead.

Working Group 1

1. What theories have been advanced by recognized commentators as to the point at which airspace (atmosphere) ends and outer space begins?
2. Under treaty and international custom, practice, and procedure, what generally by definition and judicial precedent is considered to be the upper limit of national sovereignty?
3. What are the jurisdictional and sovereign rights of nations in the airspace (atmosphere) above the terrestrial boundaries of their sovereign territories?
4. What are the rights of passage, if any, of peaceful scientific rocket (centrifugal force) vehicles through such airspace both on the occasions of launching and re-entry?
5. What is the legal status of a rocket vehicle traveling in such airspace?
6. What rights, if any, do nations have with respect to a rocket vehicle penetrating such airspace, such as the right to capture or destroy a rocket vehicle penetrating therein?
7. What is the present legal status of outer space, namely, the area of the universe beyond the airspace (atmosphere) of the earth, giving consideration to the legal effect of the acquiescence of nations to the free use of outer space by space vehicles as the result of the International Geophysical Year and of subsequent informal and formal understandings among nations?
8. Does the legal status of extra-solar space or extra-galactic space differ from the legal status of outer space comprised in our solar system or any portion thereof?

Working Group 2

1. What are the legal definitions of (a) rocket vehicle, space vehicle, or any other type of manmade instru- (CONTINUED ON PAGE 136)

Effectiveness of the Whipple meteoroid-bumper concept is evident in this sectioned test specimen, the photo of which is taken from A. E. Olshaker's MIT thesis.

State of the Art—1960

Structures and materials

By George Gerard, New York University

CHAIRMAN, ARS STRUCTURES AND MATERIALS COMMITTEE

THE PROFOUND influence of space flight and hypersonic re-entry upon structures, materials, and design concepts has resulted in a notable record of progress in these areas during the past year. This review of some of the highlights in the areas pertinent to structural design necessarily reflects a broad spectrum of activity. In the interests of solving the extremal problem of maximum information in minimum space, only a brief treatment of the individual areas can be presented.

Thermal-Protection Systems

One of the most outstanding examples of the significant rewards to be gained from an integrated approach to structures-materials systems is the success achieved in the area of thermal protection. Recognition that thermal-protection techniques cover a broad spectrum of varied application from short-time ballistic re-entry to long-time hypersonic atmospheric flight has provided intelligent guidance for major structures-materials research and development efforts.

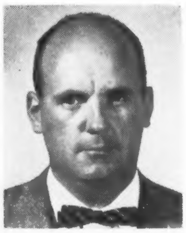
Among the noteworthy highlights in this area during the past year are broad analyses of the potentials of thermal-protection systems, the emergence of ablation as an applied science as evidenced by the relatively large number of basic papers in this area, and the development of practical radiation-cooled structures.

In the high-heat-flux drag re-entry area, developments have proceeded at a rapid pace, with the result that there are now a rather wide variety of materials available ranging from castable plastics to reinforced ceramics. The selection of materials for a particular application can now be based on efficiency rather than feasibility. Of considerable interest, too, are the development of low-heat-flux ablation-insulation coat- (CONTINUED ON PAGE 158)

Test, operations, and support

By Richard A. Schmidt, National Aeronautics and Space Administration

CHAIRMAN, ARS TEST, OPERATIONS, AND SUPPORT COMMITTEE



THE ARS Test, Operations, and Support Committee is concerned with flight, static, and environmental tests and test equipment; test operations, field operations, and commercial operations; ground-support equipment; and facilities associated with all of the foregoing. The committee was formed during the past year by a merger of the Test, Facilities, and Support Committee with the Logistics and Operations Committee.

With such a varied and intensive effort, we can only touch on the highlights of the advances made during the past year. Since our area includes the technical aspects of essentially all the other committees, some developments mentioned here are also germane to the state of the art of other technical fields. However, they are listed herein because they have important application to test, operations, or support.

The increased emphasis and activity of test, operations, and support is reflected in the great number and the high percentage of papers on these subjects presented at the XIth International Astronautical Congress last August. Ground-support equipment alone now accounts for 60 to 70 per cent of the space-system and ballistic-missile expenditure. This in itself is a measure of the state of the art of GSE, since only a few years ago only 25 to 30 per cent of our expenditure was for GSE.

Rising Requirements

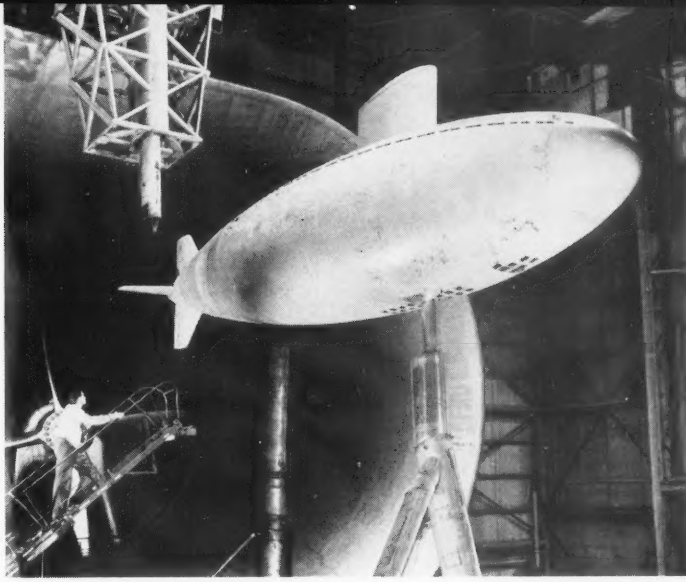
The past year has witnessed a great many successful tests of space probes, satellites, and ballistic missiles. More than twice as many large rocket-powered vehicles and missiles were launched this year than a year ago, as shown in the box score on page 64. The majority of these space exploration and military missile launches were of an R&D nature. In fact, most space flights in the next few years will be developmental flight tests. These successful launches will in turn impose more advanced requirements on test operations and ground-support equipment in the future.

The accomplishments of the past year are the result of a sizable increase in the number of skilled personnel working in this field. The gains were derived through increased (CONTINUED ON PAGE 64)

Edwards AFB Photography Branch photo

Test stand 1B, rated for 6-million-lb thrust, nears completion at Edwards AFB. This stand, with four times the rating of any other in the Free World, will be used to develop the 1.5-million-lb-thrust F-1 engine for NASA. It will be possible to mount two F-1 engines on the stand and fire them together.

The wind-tunnel testing of a scale model of the USS Albacore gives striking evidence of the growing confluence of underwater and rocket technology.



Courtesy U.S. Naval Institute

State of the Art—1960

Underwater propulsion

By George F. Wislicenus, Pennsylvania State Univ.

CHAIRMAN, ARS COMMITTEE ON UNDERWATER PROPULSION

THE ARS Committee on Underwater Propulsion held its first technical session during the Rocket Society's Semi-Annual Meeting in Los Angeles, with an attendance exceeding our expectations. It is thus justified to inquire into the reasons *why* underwater propulsion should be of such interest within a Society devoted primarily to *astronautical* propulsion and related problems.

Underwater and space propulsion have many problems in common: The unavailability of atmospheric air compels both fields to consider nuclear power or carrying the oxidizers necessary to sustain combustion. The thrust requirements in both fields range from values exceeding the terrestrial weight of the entire vehicle to a small fraction of this value, although this range in thrust is needed for different reasons. These similarities are certainly sufficient to make both fields dependent on the same underlying sciences and technologies, such as nuclear physics and engineering, fuel and combustion chemistry, and hydrodynamics. The application of these sciences to the problems of propulsion will doubtlessly constitute the principal subjects of the Society's activities.

It can be expected that nuclear power will continue to be as important for the future of underwater propulsion as it has been during the past decade. The convincing demonstration of the potential *reliability* of this new source of power in submarines should be of great value for its future use in connection with space travel. On the other hand, the weight limitations of space powerplants are sure to lead to developments of significance to vehicles submerged in water, since the everpresent demand for higher speed will make the weight of underwater powerplants as critical as for aircraft or spacecraft. One needs only to recall that the power required for underwater travel increases as the cube of the speed, meaning that an increase in speed by 50 per cent multiplies the power demand by a factor of more than three.

Hydrodynamics Especially Significant

There are many other scientific and technical areas of great importance in space as well as under water. Here we shall single out the field of *hydrodynamics*, because one could be under the impression that this field is of no major significance in space propulsion. Actually several aspects of hydrodynamics are of almost the same importance in space propulsion as in underwater propul- (CONTINUED ON PAGE 138)

ARS 15th Annual Meeting program set

Attendance of 6000 expected at the Society's largest meeting, to be held Dec. 5–8 at Shoreham Hotel in Washington . . . 36 Technical Sessions on program . . . Astronautical Exposition to feature exhibits of 80 companies . . . Honors Night Dinner, four luncheons, special sessions planned

By Roderick Hohl

ARS MEETINGS MANAGER

THE AMERICAN ROCKET SOCIETY will fittingly close out its 30th year next month with the largest Annual Meeting in its history. An attendance of 6000 is expected at the four-day meeting, to be held Monday through Thursday, Dec. 5–8, at the Shoreham Hotel in Washington, D.C.

The 15th Annual ARS Meeting will be marked by 36 Technical Sessions, covering all the astronautical disciplines, and the presentation of approximately 150 papers; the annual ARS Astronautical Exposition, also the largest in ARS history, this year participated in by some 80 companies offering displays pointing up many of the latest developments in the field in the Shoreham Exhibit Hall Dec. 6–8; the annual Honors Night Dinner; and four luncheons.

Detlev W. Bronk to Speak at Dinner

The Honors Night Dinner will be held Wednesday evening, Dec. 7, at the Sheraton Park Hotel, two blocks from the Shoreham. Main speaker at the dinner will be Detlev W. Bronk, president of the National Academy of Sciences and the Rockefeller Institute. Preceding Dr. Bronk's address will be the presentation of the seven ARS awards honoring those who have distinguished themselves in different fields of astronautics.

The four luncheons scheduled at the meeting will also be addressed by outstanding industry, government, and educational leaders. Monday's speaker will be Brig. Gen. Austin W. Betts, director of the Advanced Research Projects Agency, who will speak on this nation's ballistic-missile-defense problem and recent developments in this area. Tuesday's luncheon will be addressed by the head of the newly formed Aerospace Corp., Ivan A. Getting, who will speak on the role the company will play in the management of military space projects.

"The Generals, the Government, and Goliath" will be the title of the Wednesday luncheon talk to be given by Abe Zarem, president of Electro-Optical Systems. The final luncheon on Thursday will be addressed by ARS Director Martin Summerfield, professor of jet propulsion at Princeton University, who will speak on "Danger Signs in American Higher Education."

To fit all the Technical Sessions into the four-day program, simultaneous quadruple sessions have been scheduled throughout, except on Monday and Wednesday morning, when five sessions will run concurrently. In addition, there will be a special session Monday evening dealing with the latest developments in satellite communications, and two Tuesday evening sessions, one covering guidance and navigation and the other a classified panel discussion of "How and When Nuclear Rockets Should Be Flown," which will bring together NASA, AEC, and industry spokesmen.

Also included in the program are three sessions dealing with physics of the upper atmosphere and space. Two of these sessions under the chairmanship of Warren Berning of the Army Ordnance Ballistic Research Laboratories at Aberdeen, will deal with rocket meteorology. Included will be discussions of Hasp, a Naval meteorological rocket, Arcas, upper-air meteorology, Robin, and wind measurements.

The third session in this area will deal with solar-terrestrial relationships (see page 54).

Three sessions will be devoted to instrumentation. One will be on biomedical instrumentation, one on instrumentation for nuclear propulsion and one on instrumentation for rocket testing. Other sessions will cover human factors, thrust chamber design,

The Shoreham Hotel in Washington, D.C., scene of the ARS 15th Annual Meeting.

NASA engine programs, solid propulsion technology, astrodynamics, attitude control, electrothermal and electromagnetic propulsion, and communications.

The ARS Underwater Propulsion Committee will follow its highly succesful first session at the ARS Semi-Annual Meeting last May with a second unclassified session at this meeting. Another session will also be included on commercial applications in space.

OSR Sponsors Classified Sessions

In addition to the evening classified session on nuclear rockets, there will also be classified sessions during the day on nuclear rockets and ramjets and hybrid rockets. These sessions are under the sponsorship of the AFOSR Research Division.

ARS will hold its annual business meeting Tuesday afternoon, Dec. 6, at which time the balloting for new officers and directors will be recorded and the annual financial report given. All members are invited to attend the meeting.

Tuesday morning, the Society will institute the first of a series of ARS Section Management Forums. This session will include formal presentations on Section meeting programs and handling of Section affairs, and is open to all members. Another meeting of Section delegates will follow the annual business meeting and will be more informal, permitting discussion of Section problems. Recommendations of these two groups will be passed on to the Membership Committee for review and formal reporting to the ARS Board.

ARS will also hold its Annual Marketing Symposium, this year devoted to the subject of "Space Age Planning—1961–1970," on Wednesday afternoon. It will include eight papers covering present marketing and management problems and looking ahead to plans for the next ten years. For the first time preprints of these papers will be available at the meeting.

In addition to the regular marketing session, the ARS Exhibitors Advisory Committee has organized a session to be held Tuesday evening on national and international exhibits and the value of exhibiting to industry.

The traditional Student Conference will be held Thursday morning, at which time the two award-winning student papers will be presented and a panel of industry personnel managers will discuss careers in astronautics. This will be followed in the afternoon by an ARS Student Chapter Delegates Conference at which the problems of running a Chapter will be aired and students will be provided with an opportunity to air grievances or ask questions about chapter activities.

Complete details of the technical program are carried on the following pages.

ARS 15th Annual Meeting Program

Monday, December 5

HUMAN FACTORS CONSIDERATIONS IN SPACE VEHICLE CONTROL

9:00 a.m. **Park Room**

Co-Chairmen: Edward R. Jones, McDonnell Aircraft Corp., St. Louis, Mo.; Charles O. Hopkins, Hughes Aircraft Co., Culver City, Calif.

✦Early Development of Space Vehicle Attitude Control and Display Philosophy, John Senders, Minneapolis-Honeywell Regulator Co., Minneapolis, Minn. (1400-60)

✦Pilot Performance Capabilities during Centrifuge Simulations of Boost and Reentry, Randall M. Chambers, Aviation Medical Acceleration Laboratory, Naval Air Development Center, Johnsville, Pa. (1401-60)

✦Psychological Factors in the Manual Control of Attitude in the Mercury Vehicle, Robert Voas, Space Task Group, National Aeronautics and Space Administration, Langley Field, Va. (1402-60)

✦Advanced Display Techniques for Attitude Control of a Manned Orbital Vehicle, Donald K. Bauerschmidt, Hughes Aircraft Co., Culver City, Calif. (1403-60)

BIOMEDICAL INSTRUMENTATION FOR MAN IN SPACE

9:00 a.m. **Palladian Room**

Chairman: G. W. Hoover, Consultant, Los Angeles, Calif.

✦Where We Are Now (state of the art and knowledge) and the Potentials from Related Technology, Alfred M. Mayo, Office of Life Science Programs, National Aeronautics and Space Administration, Washington D.C. (1405-60)

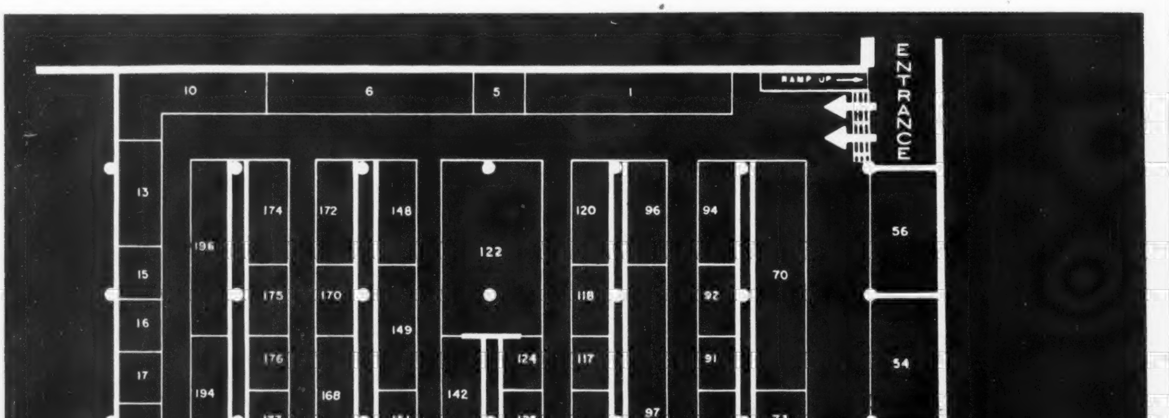
✦What is the Over-All Impact on National Health? Richard L. Masland, National Institute of Neurological Diseases and Blindness, National Institutes of Health, Washington, D.C. (1406-60)

✦What are the Requirements for Military Bioastronautics? Donald D. Flickinger, Bioastronautics, Air Research and Development Command, Andrews AFB, Washington, D.C. (1407-60)

✦What New Developments are in Process? Harry Wolbers, Douglas Aircraft Co., Inc., El Segundo, Calif. (1408-60)

ARS Astronautical Exposition

Shoreham Hotel, Washington, D.C., Dec. 6–8



NASA ENGINE PROGRAMS

9:00 a.m. Terrace Banquet Room

Chairman: A. O. Tischler, National Aeronautics and Space Administration, Washington, D.C.

✦Installation and Flight Experience with Manned Space Rocket Engines, Harry A. Koch, G. Robert Cramer, H. A. Barton, Reaction Motors Div., Thiokol Chemical Corp., Denville, N.J. (1410-60)

✦Design Approach and Salient Features of the Able/Able Star Series Propulsion Systems, David Holzman, Aerojet-General Corp., Azusa, Calif. (1411-60)

✦Agena Engine, Dave Feld, Bell Aerosystems Co., Buffalo, N.Y. (1412-60)

✦The LR115 Oxygen-Hydrogen Rocket Engine Design Concept and Development Status, R. C. Mulready, Pratt and Whitney Aircraft Div., United Aircraft Corp., United, Fla. (1413-60)

✦Development of Large Thrust Engines for Large Vehicles David Aldrich and Dominick Sanchini, Rocketdyne, Div. of North American Aviation, Inc., Canoga Park, Calif. (1414-60)

ROCKET METEOROLOGY

9:00 a.m. Main Ballroom

Chairman: Warren Berning, U.S. Army Ordance, Ballistic Research Laboratories Aberdeen Proving Ground, Md.

Vice-Chairman: Herbert Friedman, U.S. Naval Research Laboratory, Washington, D.C.

✦The Evolution of Upper Air Meteorology, Haus Aufm Kampe, Evans Signal Laboratory, Belmar, N.J. (1415-60)

✦Philosophy of the Meteorological Rocket Network, Willis L. Webb, U.S. Army Signal Missile Support Agency, White Sands Missile Range, N.M. (1416-60)

✦Hasp, An Operational Navy Meteorological Rocket, M. J. Parker, Naval Ordnance Laboratory, White Oak, Md. (1417-60)

✦Arcas, All-Purpose Sounding Rocket, Rolland Webster, Atlantic Research Corp., Alexandria, Va. (1418-60)

✦Upper Atmosphere Structure from Chemical Releases, Maurice Dubin, National Aeronautics and Space Administration, Washington, D.C. (1419-60)

✦Synoptic Studies of Atmospheric Ozone by Means of the Arcas Rocket, S. V. Venkateswaran, Institute of Geophysics, Univ. of Calif., Los Angeles, Calif. (1420-60)

TEST, OPERATIONS, AND SUPPORT

9:00 a.m. West Ballroom

Chairman: Harold Lipchik, American Machine & Foundry Co., Santa Barbara, Calif.

Vice Chairman: William F. Hay, Marquardt Corp., Van Nuys, Calif.

✦The Minuteman Silo Launch Tests, Leonard P. Bonifaci, Boeing Airplane Co., Seattle, Wash. (1421-60)

✦Nuclear Safety Analysis of Snap-3 for Space Missions, William Hagis, Thaddeus Dobry, and George P. Dix, The Martin Co. Baltimore, Md. (1422-60)

✦Operations Analysis—Hard vs. Mobile Deployment of ICBM, Bruce W. Davis, Defense Systems Div., General Motors Corp., Warren, Mich. (1423-60)

✦Lunar Surface Vehicle, L. L. Hofstein and A. W. Cacciola, American Machine and Foundry Co., Greenwich Conn. (1424-60)

✦Ground Equipment to Support the Saturn Vehicle and for a Lunar Probe, Georg von Tiesenhausen, George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Ala. (1425-60)

PROGRAM IN BIOLOGICAL EXPERIMENTATION

2:30 p.m. Park Room

Chairman: John P. Stapp, U.S. Air Force Aerospace Medical Center, Brooks Air Force Base, Texas

✦"Internal Animal Telemetry"—A Feasibility Test Program, Ben L. Ettelson, Wilfred N. Cooper, Merle A. Beaupre, Toby Freedman, North American Aviation, Inc., Los Angeles, Calif., Laurence G. Throssell, Wyle Laboratories, El Segundo, Calif., and Bruce Pine, Directorate of Bio-Astronautics Projects, Air Force Ballistic Missile Div., Inglewood, Calif. (1426-60)

✦Instrumentation for Project Excelsior, A. Marko and George Potor, Aerospace Medical Laboratory, Wright-Patterson AFB, Ohio. (1427-60)

(Additional Papers to be Announced)

INSTRUMENTATION FOR NUCLEAR PROPULSION

2:30 p.m. Terrace Banquet Room

Chairman: A. R. Crocker, Test Operations, General Electric Co., Idaho Falls, Idaho

✦Thermodynamic Temperature Probe, R. B. Edmonson, A. L. Hines, and W. R. Thompson, Aerojet-General Corp., Azusa, Calif. (1431-60)

✦High Temperature Fission Chambers and Ion Chambers, B. Bouricius, General Electric Co., Cincinnati, Ohio. (1432-60)

✦Pneumatic Nuclear Rocket Control System, Kenneth R. Pinckney, Marquardt Corp., Van Nuys, Calif. (1433-60)

✦Reactor Core Temperature Measurements, L. H. Shinault, Rocketdyne, Div. of North American Aviation, Inc., Canoga Park, Calif. (1434-60)

Exhibitors

Company	Booth
Acton Laboratories, Inc.	174
Aerojet-General Corp.	127
Aerolab Development Co.	104
Aeronutronic, a Division of Ford Motor Co.	56
Aeroquip Corp.	87
Aerospace Corp.	130
Air Products, Inc.	94
Allison Div. of General Motors Corp.	105
Aluminum Co. of America	45
Amco Engineering Co.	16
American Machine & Foundry Co.	187
Atlantic Research Corp.	193
Atomic International Div. of North American Aviation	40
Autonetics Div. of North American Aviation	103
Avco Research & Advanced Development Div.	162
Beckman & Whitley, Inc.	13
Bell Aerosystems Co.	141
Bendix Aviation Corp.	181
B. F. Goodrich Co.	92
Boeing Airplane Co.	179
Chrysler Corp. Defense Operations Div.	73
Chlor Alkali Div. of Food Machinery & Chemical Corp.	136
Climax Molybdenum Co.	159
Columbus Div. of North American Aviation	153
Conax Corp.	118
CTL Div. of Studebaker-Packard Corp.	110
Convair, a Division of General Dynamics Corp.	172
Consolidated Electrodynamics Corp.	139
Curtiss-Wright Corp., Propeller Div.	46
Designers for Industry, Inc.	175
Deutsch Fastener Corp.	91
D. S. D. Manufacturing Co.	177
E. I. du Pont de Nemours & Co., Inc.	30
Ford Instrument Co. Div. of Sperry Rand Corp.	32
Garrett Corp.	168
General Electric Co., Missile & Space Vehicle Div.	122
Goodyear Aircraft Corp.	107
Grumman Aircraft Corp.	196
Hamilton Standard Div. of United Aircraft Corp.	188
Haveg Industries, Inc.	10
Hughes Aircraft Co.	155
IBM Federal Systems Div.	189
International Telephone & Telegraph Corp.	70
Itek Corp.	54
Janitrol Aircraft Div. of Midland-Ross Corp.	53
John Wiley & Sons, Inc.	81
Johns-Manville	48
Le Fiell Mfg. Co.	194
Librascope, Inc.	109
Linde Co.	133
Lockheed Missile Systems Div.	96
McCormick-Selph Associates	125
Marotta Valve Corp.	151
Marquardt Aircraft Co.	75
Martin Co.	77
Missile Div. of North American Aviation	129
National Research Corp.	15
Philco Corp., G&I Div.	115
Powertron Ultrasonics	131
Pratt & Whitney Aircraft	89
Radio Corp. of America	51
Raybestos-Manhattan, Inc.	124
Raytheon Co.	1
Reeves Soundcraft	17
Republic Aviation Corp.	157
Resistoflex Corp.	148
Rocketdyne, a Division of North American Aviation	113
Rocket Engine Section, General Electric Co.	142
Servomechanisms, Inc.	167
Space/Aeronautics Magazine	117
Space Technology Laboratories	35
Sperry Gyroscope Co. Div. of Sperry Rand Corp.	83
Superior Tube Co.	137
Taylor Devices	161
Telecomputing Corp.	135
Texaco Experiment, Inc.	43
Thiokol Chemical Corp.	6
Vanguard Instrument Corp.	85
Walter Kidde & Co., Inc.	5
Westinghouse Electric Corp.	97
Wyle Laboratories	120
Wyman-Gordon Co.	18

Special Session Planned

On Sun-Earth Relationships

What is expected to be one of the most outstanding Technical Sessions at the ARS 15th Annual Meeting will be held on Monday afternoon, Dec. 5, at 2:30 p.m. Organized by the Physics of the Atmosphere and Space Committee, the session will be devoted to "Solar-Terrestrial Relationships," and will be chaired by Walter Orr Roberts, director of the NBS High-Altitude Observatory at Boulder, Colo. Papers will be presented at the session by John W. Evans of the Sacramento Peak Observatory; M. A. Ellison of the Dunsink Observatory, Dublin, Ireland; Herbert Friedman of NRL; and Syun-Ichi Akasofu and Sydney Chapman of the Geophysical Institute of the Univ. of Alaska.

THRUST CHAMBER DESIGN

2.30 p.m. — West Ballroom

Chairman: Martin Goldsmith, The Rand Corp., Santa Monica, Calif.

- Analytical and Experimental Scaling of Thrust Chambers, R. S. Pickford, R. G. Peoples and H. C. Krieg, Aerojet-General Corp., Azusa, Calif. (1436-60)
- The Structural Aspects of Compact Liquid Rocket Engines, Ira B. Madison, Rocketdyne, Div. of North American Aviation, Inc., Canoga Park, Calif. (1437-60)
- Ignition Characteristics of Metals and Alloys, L. E. Dean and W. R. Thompson, Aerojet-General Corp., Sacramento, Calif. (1438-60)
- Analysis of Convective Heat Transfer in Rocket Nozzles, Ernest Mayer, National Engineering Science Co., Pasadena, Calif. (1439-60)
- Two Dimensional Heat Transfer in Rocket Thrust Chamber Coolant Tubes, T. B. Davey, Aerojet-General Corp., Sacramento, Calif. (1440-60)

SOLAR-TERRESTRIAL RELATIONSHIPS

2:30 p.m. — Main Ballroom

Chairman: Walter O. Roberts, High Altitude Observatory, University of Colorado, Boulder, Colo.

- Optical Observation of Solar Activity, John W. Evans, Sacramento Peak Observatory, Sunspot, N.M. (1441-60)
- Solar Flares and Their Effects, M. A. Ellison, Dunsink Observatory, Dublin, Ireland. (1442-60)
- Variations of Solar Emission, Ultraviolet and X-Ray Regions of the Spectrum, Herbert Friedman, Naval Research Laboratory, Washington, D.C. (1443-60)
- A New Theory of the Aurora Polaris, Syun-Ichi Akasofu, Geophysical Institute, University of Alaska, College, Alaska, and Sydney Chapman, Geophysical Institute, University of Alaska, College, Alaska, and High Altitude Observatory, University of Colorado, Boulder, Colo. (1444-60)

Tuesday, December 6

ASTRODYNAMICS

9:00 a.m. — West Ballroom

Chairman: Robert M. L. Baker, Jr., Dept. of Astronomy, University of California, Los Angeles, Calif.

- The Effects of Plane Librations on the Orbital Motion of a Dumbbell Satellite, John P. Moran, Therm Advanced Research Ithaca, N.Y. (1446-60)
- Hodograph Analysis of the Orbital Transfer Problem for Coplanar, Non-aligned Elliptical Orbits, Samuel P. Altman and Josef S. Pistiner, The Martin Co., Denver, Colo. (1447-60)
- Satellite Orbit Sustaining Techniques, Richard W. Bruce, Space Technology Laboratories, Los Angeles, Calif. (1448-60)
- Rocket Boost Vehicle Mission Optimizations, R. T. Stancil and L. J. Kulakowski, Convair, Div. of General Dynamics Corp., Fort Worth, Texas. (1449-60)

INSTRUMENTATION AIDS TO ROCKET TESTING

9:00 a.m. — Palladian Room

Chairman: Edward Cartotto, Rocketdyne, Div. of North American Aviation, Inc., Canoga Park, Calif.

- Rocket Test Data Systems, R. H. Dow, Aerojet-General Corp., Sacramento, Calif. (1451-60)
- Life Testing and the Use of Statistics, Paul R. Rider, Applied Mathematics Research Laboratory, Wright-Patterson AFB, Ohio. (1452-60)
- The Standards Laboratory and Rocket Testing, Charles M. Herzfeld, National Bureau of Standards, Washington, D.C. (1453-60)
- Advancement in Instrumentation Through Continuing Development and Service, Jack C. Hoagland, Ralph H. Parsons Co., Pasadena, Calif. (1454-60)

SOLID PROPULSION TECHNOLOGY

9:00 a.m. — Park Room

Chairman: Robert A. Wasel, National Aeronautics and Space Administration, Washington, D.C.

Vice-Chairman: Edward J. Sheehy, Allegany Ballistic Laboratory, Cumberland, Md.

- Propulsion for the Scout Vehicle, R. D. Smith and J. G. Thibodaux, Jr., Langley Research Center, Langley Field, Va. (1461-60)
- Capabilities of Solid Propellant Rocket Engines in Spacecraft Propulsion, Winston Gin, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. (1462-60)
- Hypergolic Systems for the Ignition of Large Solid Propellant Rocket Motors, Joseph Priapi, United Technology Corp., Sunnyvale, Calif. (1463-60)
- Sounding Rockets—Requirements and Accomplishments, R. G. Vandevrede, J. H. Grover and W. H. Sargent, Atlantic Research Corp., Alexandria, Va. (1464-60)
- The Effect of Propulsion Costs on Stage Ratios, L. Shenfil and R. F. Tangren, Aerojet-General Corp., Sacramento, Calif. (1465-60)
- Low-Cost, All-Solid Propellant Launch Vehicles for Large Orbital Payloads, H. L. Thackwell, Jr., Grand Central Rocket Co., Redlands, Calif. (1466-60)

ROCKET METEOROLOGY

9:00 a.m. — Terrace Banquet Room

Chairman: Warren Berning, U. S. Army Ordnance, Ballistic Research Laboratories, Aberdeen Proving Ground, Md.

Vice-Chairman: Herbert Friedman, U. S. Naval Research Laboratory, Washington, D.C.

- Radiosonde Set AN/DMQ-6—Progress Report, Arthur Coppola, Evans Signal Laboratory, Belmar, N.J. (1467-60)
- The Use of Chaff in High-Altitude Wind Measurements, Lawrence B. Smith, Sandia Corp., Sandia Base, Albuquerque, N.M. (1468-60)
- Robin—A Meteorological Sensor, Robert Leviton and William Palmquist, Air Force Cambridge Research Laboratories, Lawrence G. Hanscom Field, Bedford, Mass. (1469-60)
- Proposed Water Vapor Instrumentation for the Meteorological Rocket, John A. Brown, Ballistic Research Laboratories, Aberdeen Proving Ground, Md. (1470-60)
- Seasonal, Latitudinal and Diurnal Variations in the Upper Atmosphere Measured with the Rocket Grenade Experiment, William Nordberg, Goddard Space Flight Center, National Aeronautics and Space Administration, Washington, D.C. (1471-60)
- Time-Section and Hodograph Analysis of Churchill Rocket and Radiosonde Winds and Temperatures, Sidney Tewels, Massachusetts Institute of Technology, Cambridge, Mass. (1472-60)
- Wind and Circulation in the Mesosphere, Thomas Keegan, Air Force Cambridge Research Laboratories, Lawrence G. Hanscom Field, Bedford, Mass. (1473-60)

ASTRODYNAMICS

2:30 p.m. — West Ballroom

Chairman: Joseph Siry, Goddard Space Flight Center, National Aeronautics and Space Administration, Washington, D.C.

- A General Survey of Minimum Energy Transfers and Rendezvous Using Impulsive Thrust, Wayne Templeman, Convair-Astronautics, San Diego, Calif. (1474-60)
- 1960 Advances in Astrodynamics, Robert M. L. Baker, Jr., Dept. of Astronomy, University of Calif., Los Angeles, Calif. (1475-60)
- Rapid Determination of the Interaction Between the Rocket Vehicle and Its Trajectory, Richard J. Pollak, Palo Alto, Calif. (1476-60)

(Additional Papers to be Announced)

MAGNETOHYDRODYNAMICS

2:30 p.m. — Terrace Banquet Room

Chairman: Allen E. Fuhs, Space Technology Laboratories, Inc., Los Angeles, Calif.

Vice Chairman: Jack L. Kerrebrock, Daniel and Florence Guggenheim Jet Propulsion Center, California Institute of Technology, Pasadena, Calif.

- (To be Announced), Sanborn C. Brown,

Massachusetts Institute of Technology, Cambridge, Mass. (1456-60)

✦Low Speed Plane Couette Flow of a Rarefied Conducting Gas in a Uniform Transverse Magnetic Field, H. C. Yang, Engineering Center, University of Southern California, Los Angeles, Calif. (1457-60)

✦Ionization Nonequilibrium in Expanding Flow, Allen H. Eschenroeder, and J. W. Daiger, Cornell Aeronautical Laboratories, Buffalo, N.Y. (1458-60)

✦Generalization of Oseen's Solution to Magnetohydrodynamics, M. C. Gourdine, Plasmadyne Corp., Santa Ana, Calif. (1459-60)

✦The Traveling Wave Pump, E. G. Covert and C. W. Halzeman, Naval Supersonic Laboratory, Massachusetts Institute of Technology, Cambridge, Mass. (1460-60)

NUCLEAR ROCKETS AND RAMJETS

(Secret)

2:30 p.m. — **Main Ballroom**

Chairman: C. J. Wang, Propulsion Laboratory, Space Technology Laboratories, Inc., Los Angeles, Calif.

Vice-Chairman: Robert W. Bussard, Los Alamos Scientific Laboratory, Los Alamos, N.M.

✦Nuclear Reactors for Ramjet Propulsion, T. C. Merkle, Radiation Laboratory, University of California, Livermore, Calif. (1484-60)

✦Design Analysis of a W-UO_2 Fuel Element, BeO Moderated, Be Reflector, Heterogeneous Reactor for Space Rockets, H. A. Ellerbrock and R. A. Duscha, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. (1485-60)

✦Kiwi-A Prime and Kiwi-A3 Design Description and Test Results, R. P. Durham, Los Alamos Scientific Laboratory, Los Alamos, N.M. (1486-60)

✦Rover Field Test Facilities and Operations, K. Boyer, Los Alamos Scientific Laboratory, Los Alamos, N.M. (1487-60)

COMBUSTION INSTABILITY

2:30 p.m. — **Park Room**

Chairman: Luigi Crocco, Princeton Univ., Princeton, N.J.

Vice Chairman: Jerry Grey, James Forrestal Research Center, Princeton Univ., Princeton, N.J.

✦On the Effect of Fuel Composition on High Frequency Oscillations in Rocket Motors Burning Premixed Hydrocarbon Gases and Air, J. R. Osborn and J. M. Bonnell, Purdue Univ., Lafayette, Ind. (1489-60)

✦The Inherent Stability of the Combustion Processes, R. S. Pickford, Jr. and R. G. Peoples, Aerojet-General Corp., Azusa, Calif. (1490-60)

✦Transverse Combustion Instability in Liquid Propellant Rocket Motors, Luigi Crocco, David T. Harrje and Frederick H. Reardon, Princeton Univ., Princeton, N.J. (1491-60)

✦Combustion Instability in Solid Propellant Rockets, E. W. Price, U.S. Naval Ordnance Test Station, China Lake, Calif. (1492-60)

HOW AND WHEN NUCLEAR ROCKET VEHICLES SHOULD BE FLOWN

(Panel—Secret)

8:00 p.m. — **Main Ballroom**

Moderator: Jack Armstrong, Atomic Energy Commission, Germantown, Md.

Keith Boyer, Los Alamos Scientific Laboratory, Los Alamos, N.M.

Richard Canright, National Aeronautics and Space Administration, Washington, D.C.

Krafft A. Ehricke, Convair-Astronautics Div., San Diego, Calif.

Harold Finger, National Aeronautics and Space Administration, Washington, D.C.

Maxwell W. Hunter, Douglas Aircraft Co., Santa Monica, Calif.

Raemer Schreiber, Los Alamos Scientific Laboratory, Los Alamos, N.M.

GUIDANCE AND NAVIGATION

8:00 p.m. — **West Ballroom**

Chairman: Peter Castruccio, Aeronca Manufacturing Corp., Baltimore, Md.

✦A Satellite Rendezvous Terminal Guidance System, Kenneth S. Stessan, Aerospace Corp., El Segundo, Calif. (1494-60)

✦A Self-Contained Navigational System for Determination of Orbital Elements of a Satellite, K. N. Satyendra, Nortronics, Hawthorne, Calif. (1495-60)

✦Gravity Gradient Determination of the Vertical, Robert E. Roberson, Systems Corp. of America, Los Angeles, Calif. (1496-60)

✦A Proposed Terminal Rendezvous Technique, L. J. Kamm, Convair-Astronautics, San Diego, Calif. (1497-60)

Wednesday, December 7

ATTITUDE CONTROL FOR SPACE VEHICLES AND SATELLITES

9:00 a.m. — **Park Room**

Chairman: Warren Manger, Radio Corporation of America, Princeton, N.J.

✦An Inertial Sphere System for Complete Attitude Control of Earth Satellites, Karl W. Hering and Robert E. Hufnagel, The Perkin-Elmer Corp., Norwalk, Conn., and Ralph Ormsby, Bendix Systems Div., Ann Arbor, Mich. (1500-60)

✦A Method for Controlling the Attitude of a Spin Stabilized Satellite, L. H. Grasshoff, Astro-Electronics Div., Radio Corporation of America, Princeton, N.J. (1501-60)

✦Magnetic Damping of the Angular Motions of Earth Satellites, Robert E. Fischell, Applied Physics Laboratory, Johns Hopkins Univ., Silver Spring, Md. (1502-60)

✦Design of Electric Machinery for Long Time Attitude Control of Space Vehicles, Dieter L. Teuber, Huntsville, Ala. (1503-60)

✦Vertistat—An Attitude Control Using Gravity Gradient, L. J. Kamm, Convair-Astronautics, San Diego, Calif. (1504-60)

ELECTROTHERMAL PROPULSION

9:00 a.m. — **West Ballroom**

Chairman: Robert Supp, Wright Air Development Div., Wright-Patterson AFB, Ohio

Vice-Chairman: Robert Schwartz, National Aeronautics and Space Administration, Washington, D.C.

✦Arc-Jet Engine Performance—Experiment and Theory, Richard R. John, J. F. Connors, A. Mironer and H. Macomber, Avco, Research and Development Div., Wilmington, Mass. (1505-60)

✦Performance of Propellants Suitable for Electrothermal Jet Engines, John R. Jack, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. (1506-60)

✦Thermodynamic Properties of the Hydrogen, Helium and Lithium Plasmas, Henry A. McGee, Jr., Georgia Institute of Technology, Atlanta, Ga. and National Aeronautics and Space Administraton, Marshal Space Flight Center, Huntsville, Ala., and Gerhart Heckler, Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Ala. (1507-60)

✦Arc Plasma Thrusts Studies W. Stoner, Plasmadyne Corp., Santa Ana, Calif. (1508-60)

✦High Temperature Heat Transfer Apparatus Using Arc Jet, J. Cassidy, F. Martinek and Mark Ghai, Flight Propulsion Laboratory, General Electric Co., Cincinnati, Ohio. (1509-60)

✦Electrostatic Propulsion: Highlights of Monterey Conference, A. T. Forester, Electro-Optical Systems, Inc., Pasadena, Calif. (1510-60)

HYBRID ROCKETS

(Secret)

9:00 a.m. — **Main Ballroom**

Chairman: Donald J. Simkin, Ordtech Corp., Walnut Creek, Calif.

Vice-Chairman: C. M. Wong, United Technology Corp., Sunnyvale, Calif.

✦Basic Research Studies on Hybrid Combustion, C. V. Metzler and W. Moberly Rocketdyne, Div. of North American Aviation, Inc., Canoga Park, Calif. (1511-60)

✦Theoretical Performance of Hybrid Propellants, S. Stephanou, H. Uyehara, and W. H. Jones, Aeronutronic, Div. of Ford Motor Co., Newport Beach, Calif. (1512-60)

✦Advanced Hybrid Rockets, M. J. Russi, D. J. Simkin, D. A. Moberg, and D. R. Matthews, The Marquardt Corp., Van Nuys, Calif. (1513-60)

✦Development of Large Hybrid Rocket Engines, R. Zabelka, R. McAlexander, J. J. Atkins, Naval Ordnance Test Station, China Lake, Calif. (1514-60)

✦Hybrid Propellants for Underwater Ap-

Von Braun Named Chairman of 1961 ARS "Space Flight Report to Nation" Committee

Wernher von Braun, Director of NASA's George C. Marshall Space Flight Center, Huntsville, Ala., and a member of the ARS Board of Directors for the past six years, has been appointed Chairman of the 1961 ARS "Space Flight Report to the Nation" Committee. The full make-up of the Committee will be announced in the near future.

plications, S. Singer, R. Reed and M. Farber, Rocket Power/Talco, Pasadena, Calif. (1515-60)

ADVANCED NUCLEAR ROCKET PROPULSION

9:00 a.m. **Terrace Banquet Room**

Chairman: Robert Bromberg, Space Technology Laboratories, Inc., Los Angeles, Calif.

✦Vortex Gaseous Reactor Research, J. J. Keyes, Jr., Oak Ridge National Laboratory, Oak Ridge, Tenn., M. L. Rosenzweig, Space Technology Laboratories, Inc., Los Angeles, Calif., W. S. Lewellen and J. L. Kerrebrock, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. (1516-60)

✦Approximate Solution of Isentropic Swirling Flow Through a Nozzle, A. Mager, National Engineering and Science Co., Pasadena, Calif. (1517-60)

✦A Coaxial Flow Reactor—A Gaseous Nuclear Rocket Concept, H. Weinstein and R. G. Ragsdale, National Aeronautics and Space Administration, Lewis Research Center, Cleveland, Ohio. (1518-60)

✦A Propulsion System Employing a Cavity Reactor and an MHD Generator, R. Rosa, Avco-Everett Research Laboratory, Everett, Mass. (1519-60)

✦Safety Aspects of Propulsion Reactor Flight Testing, G. A. Graves, Los Alamos Scientific Laboratory, Los Alamos, N. M. (1520-60)

SPACE LAW AND SOCIOLOGY

9:00 a.m. **Palladian Room**

Chairman: Andrew G. Haley, Haley, Wollenberg & Bader, Washington, D.C.
Vice-Chairman: Spencer M. Beresford, Committee on Science and Astronautics, U.S. House of Representatives, Washington, D.C.

✦Progress Made in Use of Radio for Protection of Life and Property in Outer Space, Andrew G. Haley, Haley, Wollenberg & Bader, Washington, D.C. (1521-60)

✦A Program to Control Civil Liability for Damage Resulting from Outer Space Activities, Spencer M. Beresford, Committee on Science and Astronautics, U.S. House of Representatives, Washington, D.C. (1522-60)

✦Private Property Rights in Space, Paul G. Dembling, Assistant General Counsel, National Aeronautics and Space Administration, Washington, D.C. (1523-60)

✦Jurisdiction in Outer Space, William A. Hyman, Attorney, New York, N.Y. (1524-60)

✦United States Organization for Space Activities, Eilene Galloway, Committee on Aeronautical and Space Sciences, U. S. Senate, Washington, D.C. (1525-60)

Scopes of ARS Technical Committees—1960

Astrodynamics—Motions of bodies outside the earth's atmosphere

Communications and Instrumentation—Sensing, transmission, and processing of information on internal and external functioning of missiles and space vehicles

Electrical Propulsion—Application of electrical, electrostatic, and electrothermal means to the propulsion of missiles and space vehicles

Guidance and Navigation—Adjustment of location or motion of missiles and space vehicles

Human Factors and Bioastronautics—Study of man's capabilities in a space environment

Hypersonics—Motion of bodies through the atmosphere of the earth or of other celestial bodies at hypersonic speeds

Liquid Rockets—Application of fluid mechanics and thermochemistry to the propulsion of missiles and space vehicles by means of liquid propellants

Magnetohydrodynamics—Physics of plasmas and other streams wherein electrical or electromagnetic phenomena are of greater significance than inertial, viscous, or convective phenomena

Missiles and Space Vehicles—Technology of planning, designing, fabricating, and operation of complete missiles and space vehicles, and management of the entire vehicle system

Nuclear Propulsion—Application of nuclear energy to the propulsion of missiles and space vehicles

Power Systems—Provision of electrical, nuclear, mechanical, and other types of power for missiles and space vehicles

Propellants and Combustion—Physics and chemistry of reactants and working fluids suitable for missile and space vehicle propulsion

Solid Rockets—Application of fluid mechanics, thermochemistry, materials technology, and mechanical design to the propulsion of missiles and space vehicles by means of solid propellants

Space Law and Sociology—Application of juridical and sociological principles to the development of astronautics for the good of man

Space Physics—Physics of the atmosphere of celestial bodies and of the matter and fields in space, particularly observational physics made possible by satellites, interplanetary probes, and space vehicles

Structures and Materials—Research, development, and application of new materials and structural principles to missile and space vehicle design

Ramjets—Application of the principle of propulsion by utilization of surrounding gaseous or particulate matter to missiles and space vehicles

Test, Operations, and Support—Planning, design, installation, and operation of facilities and ranges for the testing and operational support of missiles, space vehicles, and major subsystems

Underwater Propulsion—Application of fluid mechanics and other energy conversion techniques to the propulsion of vehicles operating in liquid media such as water

NOTE: Some further consolidation of ARS Technical Committee activity is expected in the near future.

COMMUNICATIONS

2:30 p.m.

Chairman: (To be Announced)

- ✦Tiros Operations and Performance, Sidney Sternberg and A. Schnapf, Astro-Electronic Div., Radio Corp. of America, Princeton, N.J. (1526-60)
- ✦Processing and Presentation of Digital Data from Outer Space: Explorer VI "Paddlewheel" Satellite, J. M. Seehof, Space Technology Laboratories, Inc., Los Angeles, Calif. (1527-60)
- ✦Coded Phase-Coherent Communication Systems, Andrew J. Viterbi, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif. (1528-60)
- ✦A New Approach to Space Communications During Reentry, Henri Hodara, The Hallicrafters Co., Chicago, Ill. (1529-60)

ELECTROMAGNETIC PROPULSION

2:30 p.m.

Chairman: Milton M. Slawsky, Air Force Office of Scientific Research, Air Force Research Div., Washington, D.C.

Vice-Chairman: James R. Patton, Jr., Office of Naval Research, Washington, D.C.

- ✦Some Aspects of the Hall Effect in Crossed Field MHD Accelerators, Boris Podolsky and A. Sherman, General Electric Co., Cincinnati, Ohio. (1531-60)
- ✦Plasma Acceleration by a Quasi-Static RF Electric Field Gradient, T. T. Reboul, G. D. Gordon and G. A. Swartz, Radio Corporation of America, Princeton, N. J. (1532-60)
- ✦Two-Fuid Model for the Motion of a Rarified Plasma Accelerated by Induction A. S. Penfold, Litton Industries, Inc., Beverly Hills, Calif. (1533-60)
- ✦Plasma Propulsion with a Pulsed Transmission Line, Allan Schaffer, Space Technology Laboratories, Inc., Los Angeles, Calif. (1534-60)
- ✦Experimental Performance of a Pulsed Gas Entry Coaxial Plasma Accelerator, G. Gorowitz, and P. Gloersen, General Electric Co., Philadelphia, Pa. (1535-60)

GUIDANCE AND NAVIGATION

2:30 p.m. **Main Ballroom**

Chairman: Peter Castruccio, Aeronca Manufacturing Corp., Baltimore, Md.

- ✦Considerations about a Guidance and Control System for a 24-hour Communication Satellite Launched with a Saturn Vehicle, Walter Haeussermann, Guidance and Control Div., George C. Marshall Space Flight Center, National Aeronautics and Space Administration, Huntsville, Ala. (1479-60)
- ✦A Proposed Control System to Facilitate the Terminal Phase of Manned Rendezvous, Edward Simon, Jr., Missile and Space Vehicle Dept., General Electric Co., Philadelphia, Pa. (1480-60)
- ✦Preliminary Design of a Satellite Rendezvous Vehicle, George H. Parker and William A Daly, Convair-Astronautics, San Diego, Calif. (1481-60)
- ✦Orientation Sensing in Inertial Space by Celestial Pattern Recognition Techniques, Norman S. Potter, W. L. Maxson Corp., New York, N.Y. (1482-60)
- ✦The Controlled Rendezvous of Orbiting Space Stations, Norman S. Potter, W. L. Maxson Corp., New York, N.Y. (1483-60)

SPACE LAW AND SOCIOLOGY

2:30 p.m.

Chairman: Victor L. Anfuso, Committee on Science and Astronautics, U.S. House of Representatives, Washington, D.C.

Vice-Chairman: Philip B. Yeager, Special Consultant, Committee on Science and Astronautics, U.S. House of Representatives, Washington, D.C.

- ✦Space Money, Franco Fiorio, United States Liaison Officer, Italian Commission on Space Research, Arlington, Va. (1540-60)
- ✦Some Extraordinary Implications of Kepler's Somnium, R. E. Hohmann, International Business Machines Corp., Kingston, N.Y. (1541-60)
- ✦National Security Interest in Space Law, Chester C. Ward, Rear Admiral, USN (retired). (1542-60)
- ✦International Cooperation in Astronautics Ralph E. Becker, Brookhart, Becker & Dorsey, Washington, D.C. (1543-60)
- ✦Legislative Program for Astronautics, Victor L. Anfuso, Committee on Science and Astronautics, U. S. House of Representatives, Washington, D.C. (1544-60)

Honors Night Dinner Speaker

Detlev W. Bronk

- ✦Nationality and Sovereignty of Celestial Bodies, Philip B. Yeager, Committee on Science and Astronautics, U.S. House of Representatives, Washington, D.C. (1545-60)

MARKETING SYMPOSIUM SPACE AGE PLANNING—1961-1970

2:00 p.m. **Sheraton-Park Hotel**

- ✦Obtaining Market Intelligence in the Defense Industry, John Kelly, Mgr. Market Research, Convair Astronautics, San Diego, Calif. (1546-60)
- ✦Teamwork with a Potential Competitor, C. M. Mooney, Mgr. of Government Relations, ITT Laboratories, Inc., Washington, D.C. (1547-60)
- ✦Marketing Ground Support Equipment in Systems Planning, R. E. Remley, Mgr. of Sales Planning, American Machine & Foundry, Washington, D.C. (1548-60)
- ✦Marketing Approach to Architectural and Engineering Services, K. A. Roe, Executive Vice-President, Burns & Roe, New York, N.Y. (1549-60)
- ✦The Impact of the Space Age on Aircraft Contractor, W. B. Dennis, Dir. of Development Planning, Northrop Corp., Beverly Hills, Calif. (1550-60)
- ✦The Electronics Industry in Systems Management, James Burns, Dir. of Long Range Planning, Bendix Systems Div., Ann Arbor, Mich. (1551-60)
- ✦Growth and Diversification for the Propulsion Contractor, David A. Young, Dir. of Corporate Long Range Planning, Aerojet-General Corp., Azusa, Calif. (1552-60)
- ✦Defense Industry Structure—1970, David C. Eaton, Dir. of Corporate Planning, Thiokol Chemical Corp., Bristol, Pa. (1553-60)

HONORS NIGHT DINNER

7:00 p.m. **Sheraton-Park Hotel Sheraton Hall**

Presiding: Howard S. Seifert, President, American Rocket Society

Speaker: Detlev W. Bronk, President, National Academy of Sciences

Award Presentations:

ROBERT H. GODDARD MEMORIAL AWARD

G. EDWARD PENDRAY AWARD

ARS PROPULSION AWARD

JAMES H. WYLD MEMORIAL AWARD

ARS ASTRONAUTICS AWARD

ARS CHRYSLER CORP. STUDENT AWARD

ARS THIOKOL AWARD

FELLOW MEMBER ANNOUNCEMENTS

Thursday, December 8

HYPERSONICS

9:00 a.m. **West Ballroom**

Chairman: George E. Solomon, Space Technology Laboratories, Inc., Los Angeles, Calif.

Vice-Chairman: Otto Klima, Missile and Space Vehicles Dept., General Electric Co., Philadelphia, Pa.

- ✦The Capabilities of the Shock Tunnel in the Study of the Aerodynamics of Atmospheric Entry, Walter R. Warren and E. M. Kaegi, Space Sciences Laboratory, General Electric Co., Philadelphia, Pa. (1554-60)
- ✦A Study of the Maneuvering Performance of Lifting Reentry Vehicles, Donald S. Mandell, General Electric Co., Philadelphia, Pa. (1555-60)
- ✦A Look at the Heat Transfer Problem at Super-Satellite Speeds, Mac C. Adams, Avco-Everett Research Laboratory, Everett, Mass. (1556-60)
- ✦Hypersonic Flow on the Windward Side of a Pointed Lifting Delta, H. Kennet, Boeing Airplane Co., Seattle, Wash. (1557-60)
- ✦The Aerodynamic and Radiant Heat Input to Space Vehicles Which Re-enter at Satellite and Escape Velocity, M. L. Brunner, General Electric Co., Philadelphia, Pa. (1558-60)

(Additional Papers to be Announced)

COMMERCIAL APPLICATIONS OF MISSILES AND SPACECRAFT

9:00 a.m. **Main Ballroom**

Chairman: R. B. Demoret, The Martin Co., Denver, Colo.

- ✦Commercial Communications Satellite, Harold A. Rosen, Hughes Aircraft Co., Culver City, Calif. (1559-60)
- ✦The Big Bounce for International Communications, H. E. Weppler, American Telephone and Telegraph Co., New York, N.Y. (1560-60)

SYNOPSIS OF ARS SPACE POWER SYSTEMS CONFERENCE

(Panel)

9:00 a.m. **Park Room**

Chairman: Harold B. Finger, National

(CONTINUED ON PAGE 171)

Astrodynamics

(CONTINUED FROM PAGE 30)

as any other, and all of the technical papers in a given division should be examined by the conscientious researcher. For this purpose it has been found desirable to simply list the authors contributing to any given field of astrodynamics and refer the interested reader's attention to the preprint for greater details as to the extent of their contribution and the exact reference.

Geometry and Coordinate System

Ehricke
Gedeon
McCauley
Schilt
Van Driest
Van de Kamp

Astrodynamic Constants

Alexandrov
Anderle
Brandt
Chamberlain
Clemence
Cohen
Cole
Ehricke
Firsoff
Gazley
Golay
Herrick
Jacchia
Jastrow
King-Hele
Kopal
MacDonald
Makemson
Martin
McGuire
Morrison
Murray
O'Keefe
Öpik
Paetzold
Priester
Rabe
Sehnal
Singer
Walker
Westrom
Wong
Zschorner

Orbit Determination

Anderson
Baker
Batrakov
Besag
Conti
Deutsch
Dicke
Duke
Guier
Herget
Jahontova
Kulikov
Kizner
Kranjc
Krotkov
Weiffenbach
Weirach

N-Body Problem

Duboshin
Ehricke
Grobner
Jarov-Jarovoj
Klemperer
Kozai
Leimanis
Merman
Rauch
Safronow
Sehnal
Thuring
Whitney

Special Perturbations

Baker
Brenner
Brillouin
Fulton
Garofalo
Gawlowicz
Gedeon
Gersten
Hall
Herrick
Hilton
Knoll
Lur'e
Mace
Makarov
Merrilees
Moe
Myachin
Payne
Pines
Schlesinger
Sherman
Socilina
Sperling
Thomas
Walker
Walters
Westrom
Wolfe

General Perturbations

Anthony
Balie
Bass
Batrako
Blitzer
Brenner
El'yasberg
Ewart
Fosdick
Galowicz
Garfinkle
Geyling
Glitzer
Grebenikov
Heinrich
Hori
King-Hele
Kovalevsky
Kozai
Lanzano
Ljah
Moe
Musen
Penzo
Proskurin
Slotnick
Upton
Vinti
Walker

Non-Gravitational Forces

Arthur
Bailie
Beard
Benedikt
Bogorodskii
Bryant
Chahine
Chang
Cohen
Geyling
Hewitt
Huth
Johnson
Jones
Karrenberg
Kraus
Lapaz
Lillestrand
London
Maslach
Maulic
Mikhailov
Musen
Nagamatsu
Parkinson
Rand
Rider
Schaaf
Schmid
Schrello
Shapiro
Sheer
Smith
Stark
Szebehely
Westerman
Wilson
Wyatt
Yoshihara

Observation Theory

Bajcar
Brandenberger
Cohen
Danjon
Dubner
Fricke
Frye
Gabbard
Gourko
Gibson
Haywood
Hertz
Hynek
Jeffers
Kahn
Kastaanheimo
Kemper
Koskela
Krampe
Lillestrand
Miczaika
Murray
Neirinck
Nemiro
Nicola
Nunn
Oort
Shepler
Visnovcova
Wackernagel
Walters
Wasel
Wood

Optimization Theory

Braham
Brown
Cavoti
DeBra
Edelbaum
Fiul
Graham
Gundel
Horner
Kelley
Leitmann
Levinsky
Lorell
McGill
Miele
Munick
Nelson
Niemi
Rider
Schiller
Schindler
Silber
Skalafuris
Smith
Taylor
Vargo
Wolfe

Attitude Dynamics

Arck
Arrow
Baker
Barnes
Beletskiy
Doolin
Dubosin
Frick
Ftenakis
Garber
Gillespie
Goodstein
Grubin
Haeussermann
Hainsworth
Hanes
Karrenberg
King
Klemperer
Klondurar
Merlen
Moran
Mueller
Niday
Ormsby
Raushenbax
Reiter
Ritchie
Roberson
Roman
Thomson
Tokar
Triplett
Von Pahlen
West
Wolfe

Applications (Satellite)

Berger
DeBra
Detra
Duke
Felkman
Fitzgibbon
Friedlaender
Goldberg
Grube
Gundel
Gunkel
Harry
Herman
Hoover
Hunter
Klemperer
Nason
Petersen
Pfeffer
Loh
Morgenthaler
Pohle
Ricupito
Riddell
Roberson
Rose
Sears
Sehnal
Swanson
Vargo

Applications (Lunar)

Booton
Brand
Hoelker
Jean
Kaempen
Kierstead
Lanzano
Liu
Mickelwait
Miele
Peske
Riddell
Sedov
Stehling
Swanlund

Applications (Interplanetary)

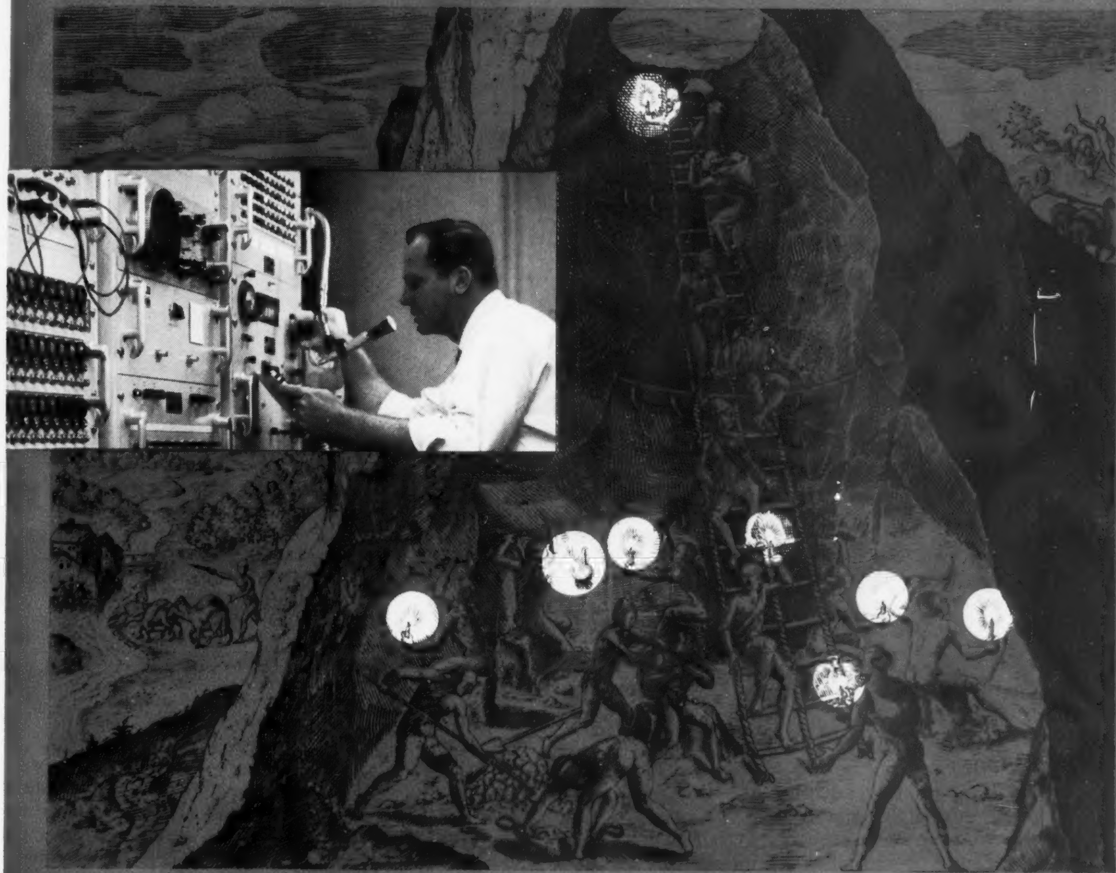
Anthony
Battin
Breakwell
Brunk
Clemence
Clohessy
DeBra
Doolin
Flaherty
Fosdick
Gillespie
Hock
Mickelwait
Nonweiler
Park
Pfeiffer
Roberson
Rodriguez
Ross
Safren
Smith
Spence
Stearns
Tanguay
Tompkins
Wiltshire
Zilczer

As far as the future of astrodynamics is concerned, the importance of education is paramount. The preprint bears witness to the fact that in 1960 alone there have been well over 200 technical papers published by over 300 authors. By far the great majority of these contributors have not had the advantage of formal astrodynamic training. In future years, as new problems arise in astrodynamics and as the study of the field reaches an even greater intensity, the requirement for formally trained scientists will be even more acute.

In answer to this challenge there are but few active educational programs in astrodynamics. MIT, Michigan, and Yale offer programs in some specialized areas of astrodynamics. Cincinnati, as reported by Rabe, offers courses in dynamical astronomy, and has produced two Master's degrees. Although Rabe feels that the turnout has been rather limited, a few gifted and mathematically well prepared graduate students have taken to the subject with real enthusiasm. UCLA, particularly if the extension offerings are included, has perhaps the nation's largest educational program in astrodynamics. Several hundred are enrolled in its space-technology courses each semester. So far there have been a half dozen Master's degrees and a Ph.D. granted, and there are about 30 regular university graduate students now enrolled in its growing Engineering-Astronomy astro-

An extensive survey of astrodynamics for 1960, covering 80 per cent of the literature published to September, or some 260 papers, is available from the American Rocket Society, 500 5th Ave., New York 36, N.Y. Ask for ARS Preprint 1475-60—"Survey of Astrodynamics 1960."

FROM CRUDE DISCOVERY TO CONTROLLED CREATION
of power and new materials within the earth's crust



Prominent among the leaders in developing nuclear power for peaceful progress are the scientists and engineers of EG&G . . . working under the aegis of project Plowshare. EG&G instrumentation systems are of primary importance in the expioitation of underground nuclear explosions (project Gnome) for the generation of electricity and the production of industrially and medically valuable isotopes.

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dynamics curricula. The Russians, according to Rabe, also concern themselves about education in the field of astrodynamics. They plan to improve the training of specialists at the universities, to raise the level of astronomy departments at a number of universities, and even to do something about the teaching of astronomy in high schools. Clearly the educational race is also on.

Although the granting of graduate degrees in astrodynamics is most important, it is of equal importance to incorporate astrodynamics as a portion of the curricula in many fields of science and engineering. A greater appreciation of the problems of astrodynamics as they relate to other scientific disciplines will surely become of increasing value as time goes on. ♦♦

Propellants and Combustion

(CONTINUED FROM PAGE 44)

for the ignition of propellant samples (Reference 1).

The subject of aging and storability of high-energy ingredients is one which is not readily dealt with in a general manner. Once a specific system is chosen, it is then necessary to select a suitable means for detecting changes as a function of time and temperature. The improvement of aging and storability is another facet of the problem. Encapsulation has been suggested as a means for improving material compatibilities. However, success along these lines has not been reported to date. In solid propellants, aging can affect both ballistic and mechanical properties. Again, the entire problem is dependent upon the specific system under consideration.

Among the four problem areas mentioned, contributions toward solution of the combustion instability problem have been most impressive. Substantial contributions toward the understanding of liquid-engine instabilities continue to appear. Efforts by the group at Purdue Univ. (2) are noteworthy. Most recent progress, however, has been made toward understanding the solid-propellant-instability problem. It must be understood in this connection that for years little progress was made in the systematic correlation of experimental parameters related to the solid-propellant-instability problem. A large body of experimental facts existed with no clearly evident trends, and sometimes they appeared quite conflicting. Work at the California Institute of Technology's Jet Propulsion Laboratory (3, 4) represents a significant stride forward in the collection of useful experimental data in the sense of more clearly defining the instability problem. By use of a rather ingenious technique, Edward Price at NOTS has also made important contributions toward isolating specific factors of interest in the instability problem (5). Finally, the theoretical work of McClure et al. at the Applied Physics Laboratory, Johns Hopkins Univ., has been of considerable value in focusing attention on important aspects of the problem and providing a general framework for the collection of additional experimental data.

In state-of-the-art propellants, as well as those high-energy systems for the future, the effects of solid particles in the exhaust assume considerable significance in determining the performance of a given propellant. One effect is that of reducing the combustion efficiency by ejection of incompletely burned particles in the exhaust. There are other effects related to the fact that flow systems contain two phases. To date, considerable progress has been made in the study of the burning of metal powders and metal hydrides in solid-propellant flames. The ARS meeting held at Princeton early this year contained a highly interesting session devoted to contributions to this problem. The photographs on page 44 were taken by Derck Gordon of the Stanford Research Institute, and show the interesting fragmentation effects obtained when titanium and magnesium-aluminum alloy are burned in an oxygen-rich gas stream.

It is well known that both liquid and solid propellants have many requirements which must be met simultaneously and which are conflicting to the degree that a compromise in properties is necessitated. High energy means low stability. Also, the elements which contribute most to high performance limit the physical properties of the corresponding propellant. This limitation is particularly severe in the case of solid propellants, where case bonding is necessary for high propellant mass fraction. Present propellant binders contain carbon. However, carbon is not a desirable constituent from the performance point of view. It is necessary, therefore, to understand and state quantitatively the mechanical property requirements of solid propellants in casebonded rocket-motor applications. An understanding of the problem requires several kinds of information: (1) The state of stress throughout a propellant grain in a rocket motor as a function of size, grain design, and temperature; (2) changes in the stress pattern induced by sudden pressurization or caused by changes in temperature; and (3) the behavior of propellant grains under a variety of conditions.

An ultimate objective is that of establishing failure criteria and scaling laws. Early work focused attention on the behavior of propellants under simple conditions such as simple tension. Recent work is directed toward an understanding of propellant failure under conditions of combined stress and these results are being directly applied to the establishment of failure criteria. In general, it can be said that more detailed studies are now under way to determine mechanical property requirements of solid propellants in solid-rocket-motor applications.

In connection with the processing of solid propellants, there has been much progress recently in the development of continuous processing techniques. Within the past year, several companies have claimed the development of successful continuous processes for state-of-the-art solid-propellant compositions for use in present missile systems.

In writing this survey, attention has been purposely called to contributions made at recent ARS meetings, since they provide examples of the technical excellence of some of the material being presented at these meetings. It is hoped that there will be an even higher percentage of these superior contributions received in the future. It should also be mentioned that the review contains much more material on solid propellants than on liquid propellants, primarily because much of the more interesting work being conducted in the liquid field is being published only in the classified literature.

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♦♦

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UAC RESEARCH

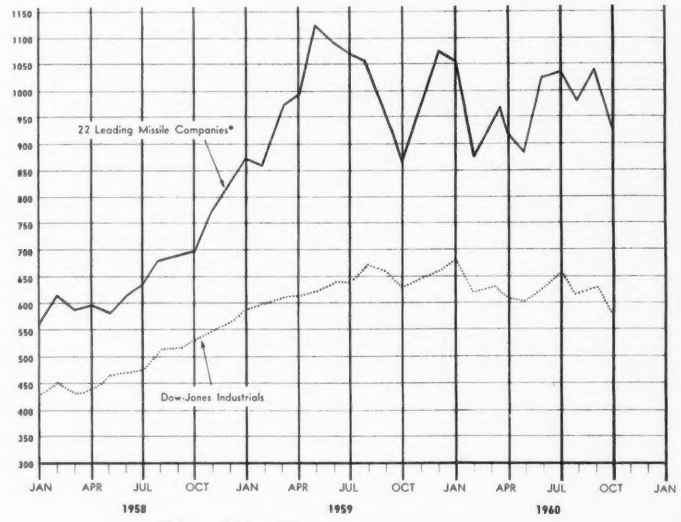
Missile market

By Jerome M. Pustilnik, *Financial Editor*

"OFTEN wrong, but never in doubt," the sobriquet cynical Wall Streeters apply to all economists (including their own) never has been earned more meritoriously than in 1960.

The Soaring Sixties, which economic prognosticators launched spaceward, accompanied by the enthusiasms usually attendant upon such a shoot, has faltered, buckled, and then, as if some range safety officer had pressed the destruct button, burst and come streaming down, trailing wreckage. And nowhere are the ruins more in evidence than in brokerage house accounts.

The damage done to many, many individual stocks is severe and their declines considerably exceed the percentage drop of the Dow-Jones Industrial Average, the most popular and widely-used yardstick. While the Dow presently is down about 16 per cent from its high (from 685 to 575), dips of 30–65 per cent are commonplace for specific securities, such as steel, oil, metal, and cyclical issues. Nor is this a recent occurrence; several groups have been working lower for longer than two years. The Missile Index established its high in May 1959, for example; and while it rallied several times in the ensuing year-and-a-half, the old high remains inviolate.



*Index compiled June, 1955

	Oct. 1960	Sept 1960	% Change	Oct 1959	% Change
Dow-Jones Industrials	580	626	−7.4	632	−8.2
Missile Index	936	1041	−10.1	870	+7.6

These technical considerations of market price action are important because they provide perspective for outlining probable future price behavior. When a stock like Douglas Aircraft, as an illustration, erodes from 75 to 30 (at this writing) in a little more than two years, it is more likely to be a candidate for purchase than for sale. The same view can be taken of the missile and defense groups, in this column's opinion. Phrasing it positively, these securities are in a buying area.

While prospects for business and the economy remain uncertain, important increases in military spending seem virtually assured, whichever candidate wins the election. (As a matter of fact, all government spending probably will be higher under the next Administration.) After a time lag of about six months, this spending will begin to have its impact upon business, and corporate countenances should brighten. As the stock market usually anticipates—by about six months—such changes in business activity, this six-month period should tend to cancel the other; and a good buying opportunity seems to be at hand. An investor displays great courage when he buys securities while everything looks black and almost everybody talks discouragingly. Certainly this is easier said than done, but worthwhile profits often are made this way.

In the January issue, Missile Market, in reviewing economic and stock market prospects, advised investors to review their holdings at mid-year and, particularly, cautioned them to be very wary of those highly speculative and promotional issues masquerading as missile industry securities. The second half of that advice is re-emphasized; and for those who neglected to review their portfolios, the stock market has since done it for them. While we believe defense issues are generally attractive, the market undoubtedly will continue to display the same agonizing selectivity that has been its hallmark. In recognition of this important characteristic, this column will try to choose specific stocks when they appear to be unusually attractive. Chance Vought and AMP, Inc., seem to be just such securities and we will discuss them in our next issue. ♦♦

NSF Offers Postdoctoral, Graduate Fellow Awards

Applications will be accepted through December 19 for National Science Foundation Postdoctoral and Graduate Fellowship awards for advanced study in the sciences. Awards will be made in the mathematical, physical, medical, biological, and engineering sciences. Applications may be obtained by writing to: Fellowship Office, NAS-NRC, 2101 Constitution Ave. N.W., Washington 25, D.C.

BENDIX EXHIBIT

15th ANNUAL MEETING
AND ASTRONAUTICAL EXPOSITION

WASHINGTON, D. C.

SHOREHAM HOTEL

DECEMBER 6, 7, 8, 1960

BOOTH NUMBERS
181, 182, 183 AND 185

THE Bendix CORPORATION

Missiles and Space Vehicles

(CONTINUED FROM PAGE 40)

Although purely missile achievements do not generate headlines as prolifically as space orbits, several notable events occurred. The Atlas ICBM continued to progress, demonstrating capability at ranges of 9000 mi; the Titan appeared to have overcome its earlier difficulties; and the Minuteman solid-propellant ICBM was expected to have its first complete missile firing by the end of this year. The first undersea launches of Polaris missiles from submerged submarines were made successfully. A contract was let for the Skybolt air-launched ballistic missile. In the defensive-missile field, several missile-to-missile interceptions were accomplished, including the interception of an Honest John by a Hawk, the interception of a Corporal by a Nike-Hercules, and the interception of a Nike-Hercules by another Nike-Hercules. The first experimental firing of the Nike-Zeus anti-ICBM took place.

In the field of future large-vehicle development for space applications, nearly all emphasis is, of course, based on the Saturn vehicle. The first firing of the eight-engine Saturn S-1 stage was successfully made at Huntsville, Alabama, in April of this year; and subsequently, a number of full-duration static firings were successfully completed. The philosophy of using a modified Titan as an upper stage on Saturn was changed to that of using hydrogen-oxygen propellants for all upper stages. A contract has been let for the second stage of the Saturn C-1 configuration. This will be the largest high-energy rocket stage under development to date. It carries of the order of 100,000 lb of hydrogen and oxygen as propellants, housed in tanks $18^1/_2$ ft in diam, the largest rocket tanks being designed at the present time. A contract has also been let for a 200,000-lb-thrust hydrogen-oxygen rocket to be used as a propulsion unit on a larger Saturn second stage. The level of development effort on the high-energy hydrogen-oxygen propellant combination has stepped up greatly, and the introduction of this combination into large-scale operational use will be one of the features of the next few years of space-vehicle development.

Nuclear Rockets Closer

The day of the nuclear-rocket engine appears to be drawing steadily closer. The second static firing of such a rocket was successfully completed, and study contracts have been let to start to explore the initial utilization of such propulsion units. Early conceptual studies have indicated that nuclear rockets will have a large impact upon the design of the space vehicle, its launch site, and stage-recovery techniques. Vehicle shapes will be altered to reduce payload shielding requirements and boil-off losses in the liquid hydrogen tanks due to nuclear radiations. This, together with the large rocket nozzle required to permit full performance availability, will mean that the marriage between the vehicle and the propulsion system will be a much closer integration than in the past.

Along with the more spectacular achievements in space are the less exotic but equally important scientific experiments gathering additional data on the time variant space environment, which is preparing the way for man's venture into space.

As the state of the art in missile and space-vehicle design steadily progresses, it would seem that the next developments will be highlighted by the employment of large quantities of high-energy propellants, development of large rockets of the Saturn category, making preparations for the adoption of nuclear powerplants, and the continuing drive to achieve reliability suitable to man-in-space operations. ♦♦

Test, Operations, and Support

(CONTINUED FROM PAGE 48)

reliability obtained by various improvements including advanced static-test techniques, better countdown and checkout procedures, and increased safety precautions. Improved reliability is also the result of better design and the use of standardized and proved components rather than increased redundancy.

A great stride has been made in the testing of rocket engines, particularly as measured in terms of pounds of thrust. The clustered 1,500,000-lb Saturn engine has been tested and more recently the single chambered F-1 engine of 1,500,000-lb-thrust has been test-fired. The development of a long duration 1,000,000-lb -thrust solid-propellant engine is under contract. These engines represent thrust increases of four to 10 over previous engines. Test facilities for these engines represent comparable increases in flow rates, number of channels of instrumentation, propellant storage capacity, high-pressure gas usage and pressure, etc.

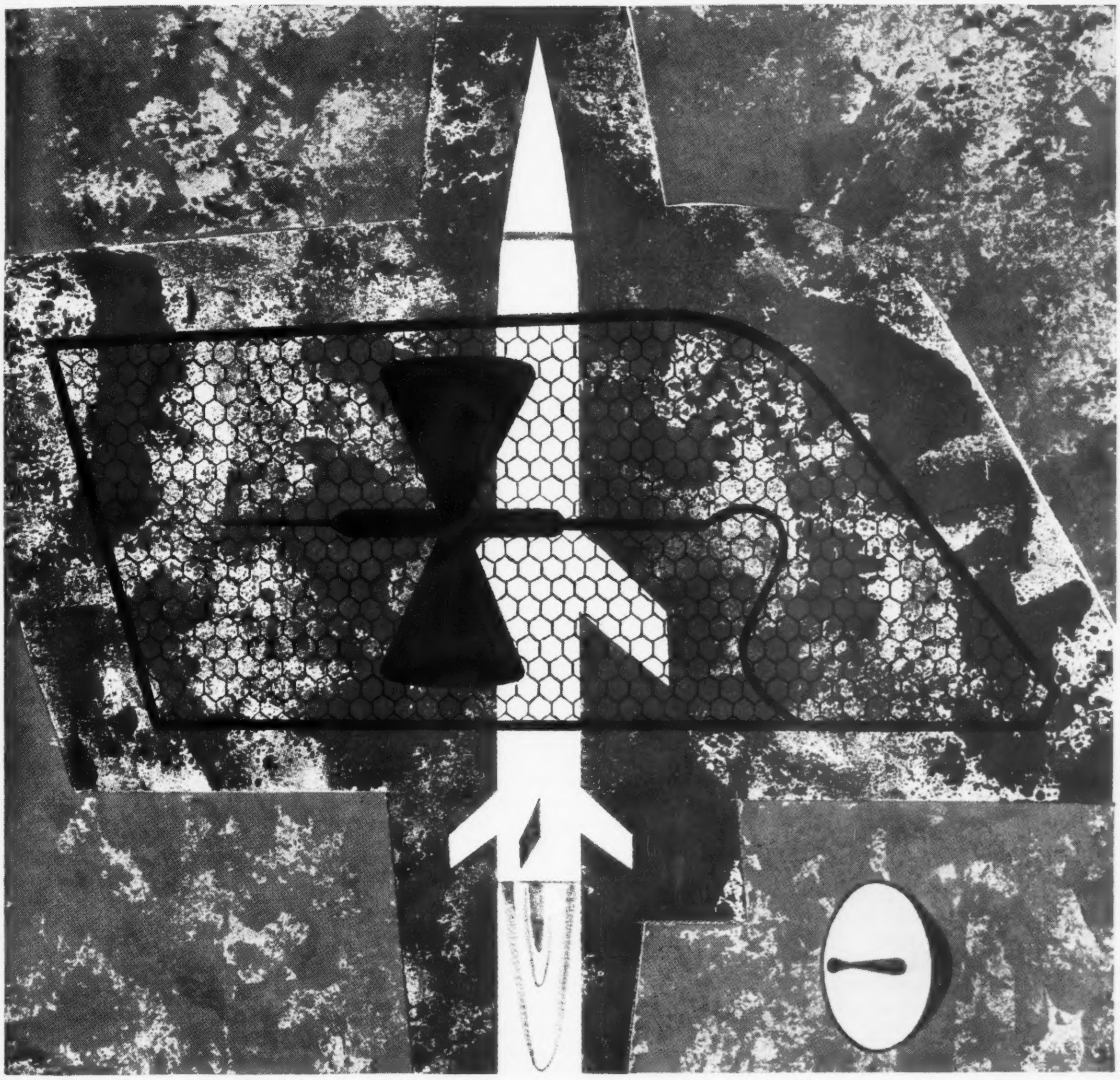
Considerable benefits have been derived from the high-altitude simulation of rocket-engine operation at the AF Arnold Engineering Development Center. The determination of base heating and solid-engine chuffing are just a few of the many benefits of this testing.

New test facilities are under construction which will improve man's ability to explore and operate in space. A 6,000,000-lb thrust static test stand is nearly completed at Edwards AFB. The next step is 30,000,000 lb. With water cooling requirements for the flame deflector becoming prohibitive, progress has been made in an anhydrous deflector. Design and fabrication of liquid hydrogen storage and transfer equipment with a capacity of 10 to 15 times that of existing equipment is under way. However, liquid hydrogen subcooling equipment is required to permit relatively long holding times in orbit. Progress has been made in the development of combined environment facilities, dynamic analyzers, and large extremely high-altitude test chambers.

Several ballistic-missile systems have become operational and several more have advanced considerably toward operational status. The rate of research and development launches has more than doubled. New systems

Space Box Score

	Launches Sept. 1, 1959—Sept. 1, 1960		Launches Sept. 1, 1958—Sept. 1, 1959	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.
Earth Orbit	13	2	7	1
Still in Orbit	8	1	2	0
Solar Orbit	1	0	1	1
Lunar Impact	0	1	0	0
Recoveries	2	1	0	0



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that have been tested include the Titan, Pershing, and Polaris. Considerable evolution has occurred in hardened sites and in mobile ballistic missiles. The entire weapon system, from sleeping pad to launching pad, is now protected from enemy nuclear attack. New spacecraft systems that have undergone initial tests include the Echo satellite and Mercury capsule. The large number and great variety of these and the many other launches provides a good measure of the substantial progress in the state of the art of test, operations, and support.

Pioneer V Records

A new record has been set in remote operation and measurement with Pioneer V operating out to 23,500,000 mi. A record was also set in the long-range and remote troubleshooting of Pioneer V at 4,800,000 mi.

Advances made in ground-support equipment include the practical application of recent innovations, as well as improved equipment designed for new projects. Tracking and telemetry equipment for Project Mercury is nearly operational, and the communication links for data acquisition, target acquisition, and operational preparation are well advanced.

Progress has been made in the use of automatic operation of checkout equipment. Designs now developed will permit the checkout of an R&D vehicle on the launch pad in a period of two weeks, where previously two months were required. A much improved vehicle tracking system is being installed at the Atlantic Missile Range. This is the Mistram system, which will permit very accurate tracking at over 1000-mi range.

Ground scanning television on a satellite with relay to ground stations has been vividly demonstrated and applied in Tiros. The transmission and distribution of data from the ground stations has been more efficient and rapid than was previously possible. The reliability of GSE has improved principally through the standardization of equipment. Many proved modules now exist for new systems that are being built. Increased use of standardized units will result in even better systems.

Character display generators of high quality have made possible the display of real-time test data previously not obtainable. Signals for the character display on cathode-ray tubes can now be transmitted over iron wire, instead of coaxial cable or microwave links.

Large-scale liquid helium handling systems have been put into operation. Cryogenic problems are being simplified by the development of direct measuring mass flow meters. With these meters it will be possible to improve the calibration of liquid rockets in terms of total impulse available. Propellant utilization to within 0.1 per cent will be achievable. Liquid hydrogen production facilities with considerably increased output are now in operation.

Although a great many gains were made in test, operations, and support during the past year, numerous improvements are still required. Environmental test facilities are needed for operational simulation of attitude control systems with the propulsion devices operating.

While advances have been made in the test firing of nuclear-rocket engines, the rate of testing of the engine will have to be increased greatly to provide a flyable engine within five or six years. More sophisticated ground tests are required. The normal development of a non-nuclear liquid-rocket engine requires thousands of static tests through the preliminary flight rating tests. Ingenuity and resourcefulness are necessary to produce a multifold increase in the effectiveness of nuclear-rocket static tests, since the rate of testing is too limited.

The development of a technique or techniques for the recovery of spacecraft is one of the biggest difficulties in the operations area. Attempts to date have been quite unsatisfactory. Better retardation and posigrade devices and operational techniques must be developed. New approaches are underway, but until propulsion is many times more efficient, we must relay on ingenuity.

Nuclear Safety at Issue

Handling and safety provisions for an on-board nuclear electrical power system have not yet evolved. There is a continuing need for improved shock suspension systems for all the components of a hard-based weapon system.

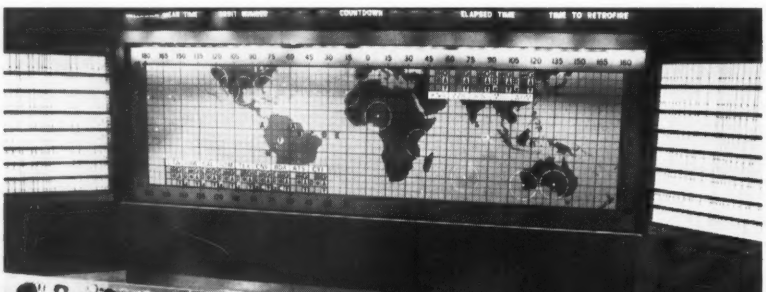
Electronic-initiated stimuli are needed for military missions. Integrated mission simulators will permit the operational crews to experience authentic actions and reactions to the operation they perform.

The most prevalent requisite of the not-too-distant future is the microminiaturization of ground-support equipment. What we now think of as ground-operation equipment will be the major portion of the payload in space exploration. Everything from ground power, tracking equipment, telemetry systems, and ground-handling equipment to housing will be needed for landing and launching from a space station and from the moon.

It is difficult to communicate with tracking sites in South Africa today. Tomorrow, we will have to communicate 50 times further, and the next day it will increase a thousandfold. At these remote distances, we on earth must monitor the countdown and record the results.

TV instrumentation for on-board looking at facts, figures, and faces is required even today. Mobile tracking sites are a continuing requirement. The advancement in the reduction in size of nuclear warheads and the rocket-powered missiles to carry them has generated a requirement for roadable ICBM launchers and supporting equipment.

The next generation of large boosters and nuclear stages need suitable launch sites. These space vehicles will put the interests of the ARS Test, Operations, and Support Committee on the moon. ♦♦



The central control room for Project Mercury vividly portrays the state of the art of manned space-vehicle operations.

Who's posting the BIG SCORE on reliability in propulsion?

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8 successful launches in 8 successive tries. Silo tests using Thiokol solid propellant first stage engines modified for this purpose have proved so gratifying, the original schedule of 18 silo test shots reduced to 8, greatly accelerating the Minuteman ICBM research and development program. Thiokol means reliability!

Associate Prime Contractors: Thiokol Chemical Corp., first stage; Aerojet-General Corp., second stage; Hercules Powder Co., third stage; Autonetics Division North American Aviation, guidance and control system; AVCO, re-entry vehicle; Boeing Airplane Co., assembly and test.

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Rocket Operations Center: Ogden, Utah

Minuteman Motors produced at the Utah Division

PERSHING

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Prime Contractor: The Martin Company. Propulsion Contractor: Thiokol.

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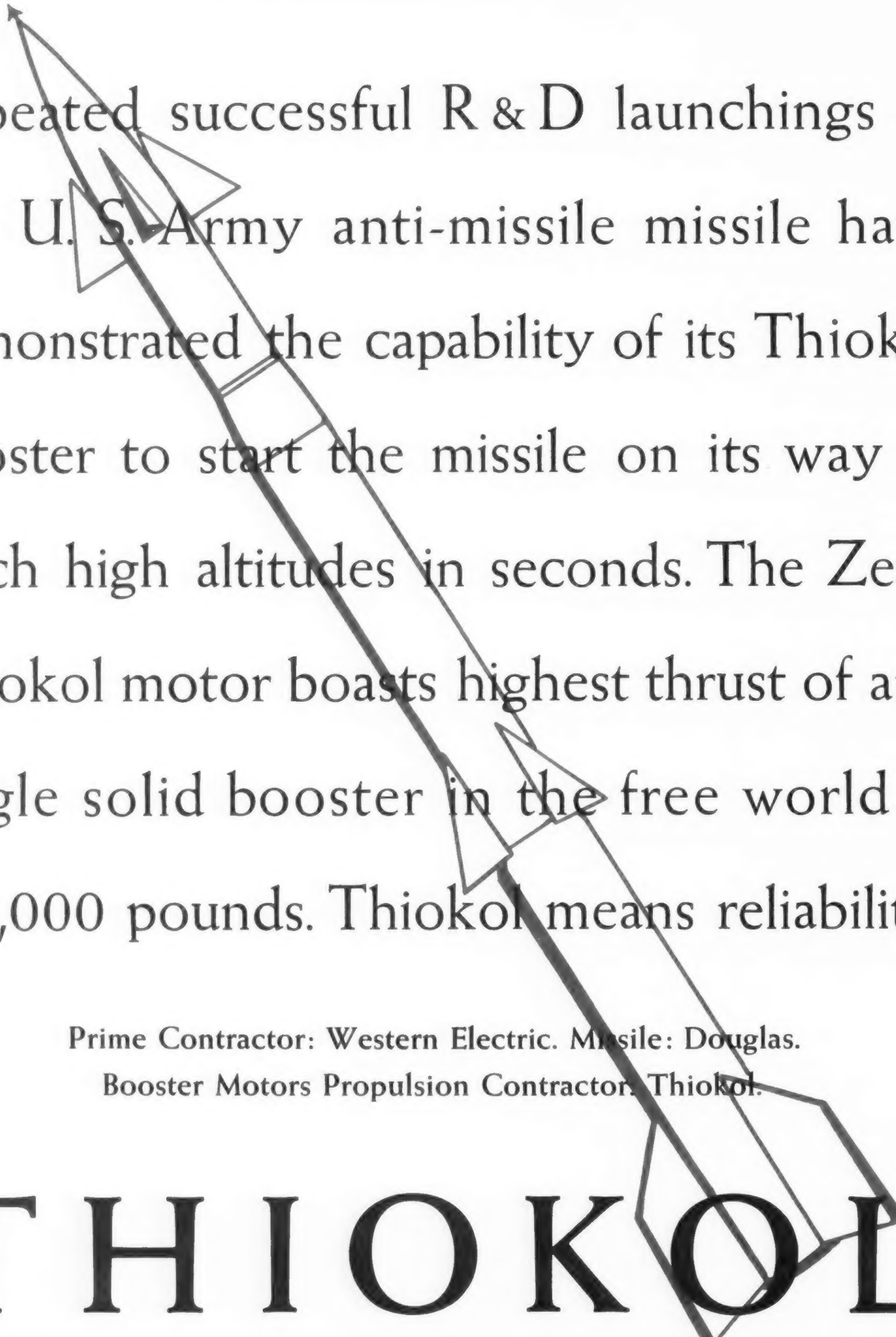
Pershing Motors produced at the Redstone Division

NIKE-ZEUS



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Prime Contractor: Western Electric. Missile: Douglas.
Booster Motors Propulsion Contractor: Thiokol.

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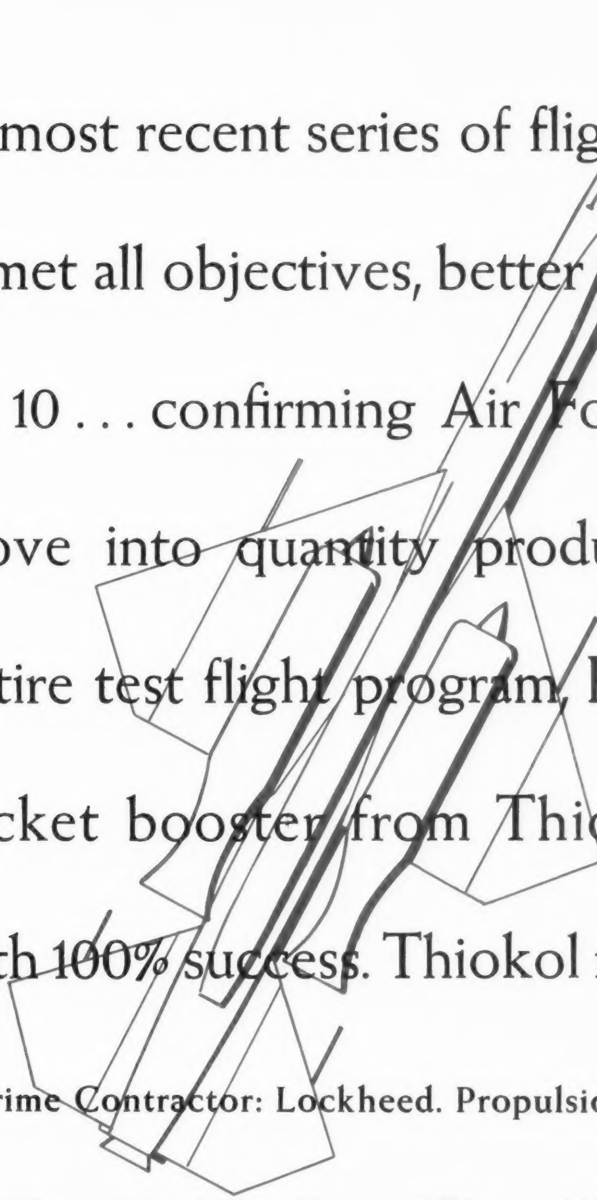
Rocket Operations Center: Ogden, Utah

Nike-Zeus Motors produced at the Redstone Division

BOMARC B



In most recent series of flight tests, Bomarc B met all objectives, better than 9 times out of 10 . . . confirming Air Force decision to move into quantity production. Through entire test flight program, Bomarc B's solid rocket booster from Thiokol performed with 100% success. Thiokol means reliability!

Prime Contractor: Lockheed. Propulsion Contractor: Thiokol

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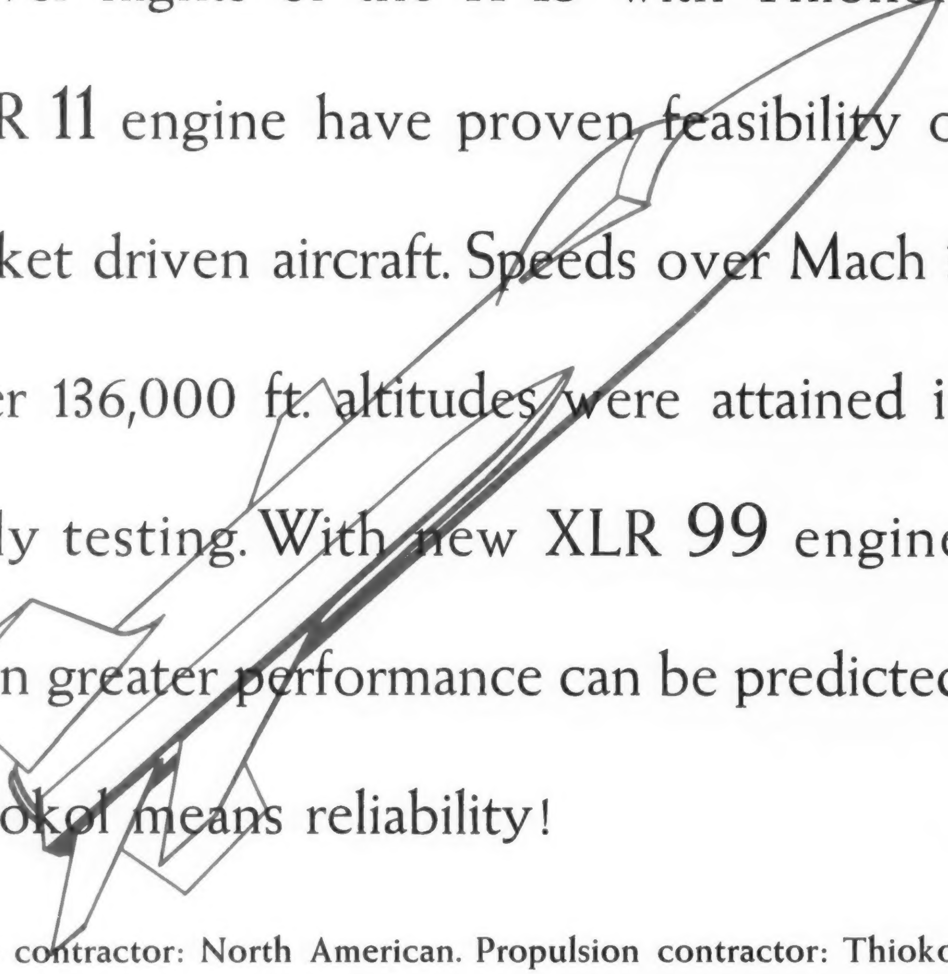
Rocket Operations Center: Ogden, Utah

Bomarc B motors produced at the Utah Division

PULL OUT

X-15

Power flights of the X-15 with Thiokol's XLR 11 engine have proven feasibility of rocket driven aircraft. Speeds over Mach 3, over 136,000 ft. altitudes were attained in early testing. With new XLR 99 engine, even greater performance can be predicted. Thiokol means reliability!



Prime contractor: North American. Propulsion contractor: Thiokol.

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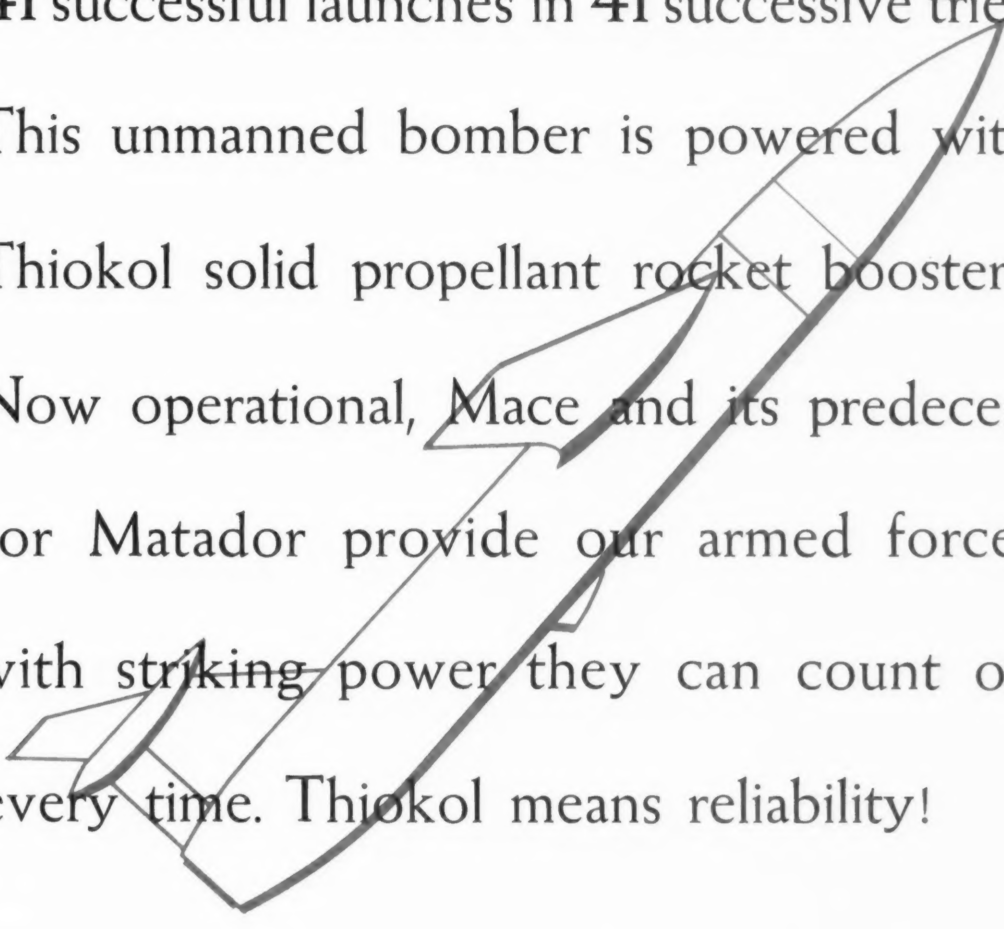
Rocket Operations Center: Ogden, Utah

X-15 engine produced at Reaction Motors Division

MACE

41 successful launches in 41 successive tries. This unmanned bomber is powered with Thiokol solid propellant rocket boosters. Now operational, Mace and its predecessor Matador provide our armed forces with striking power they can count on every time. Thiokol means reliability!



Prime Contractor: The Martin Company. Booster Contractor: Thiokol.

THIOKOL

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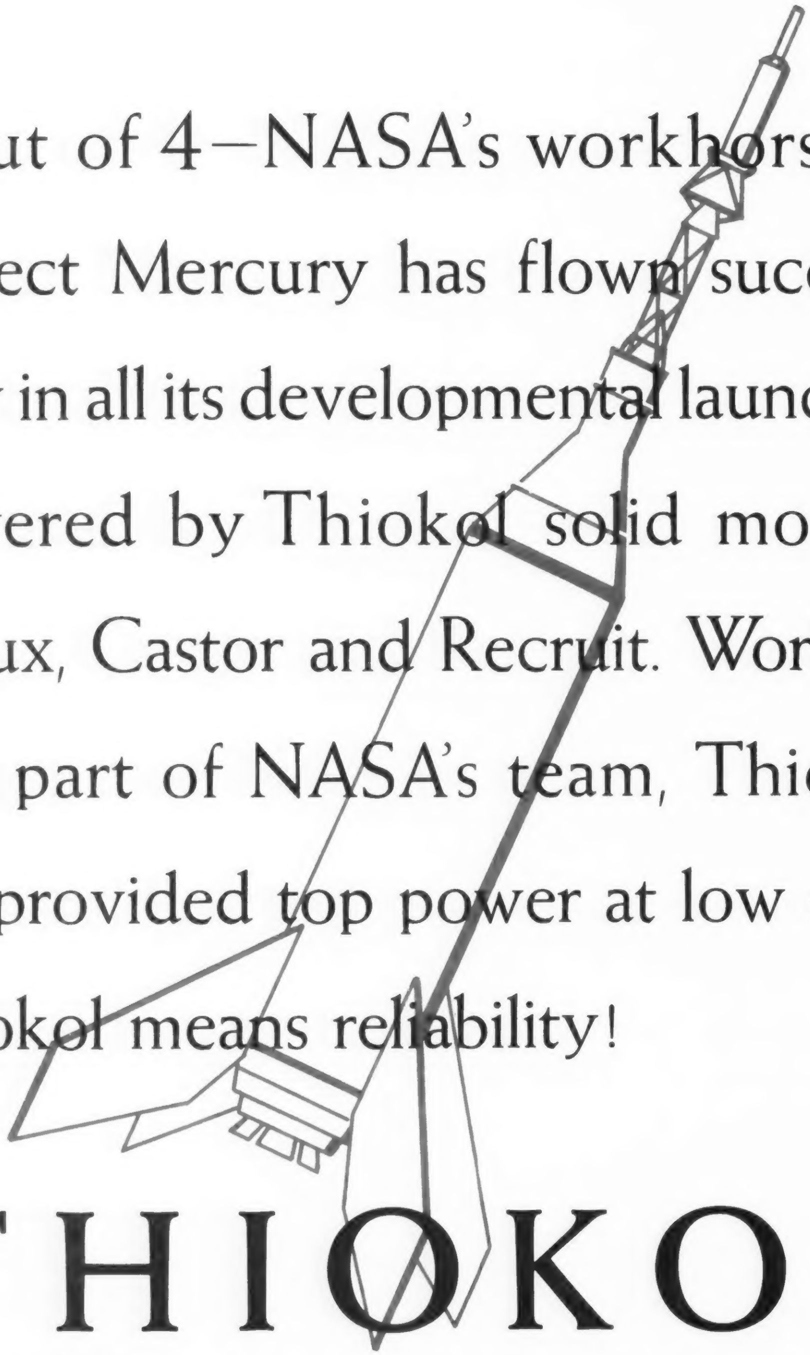
Rocket Operations Center: Ogden, Utah

Mace Motors produced at the Utah Division

LITTLE JOE



4 out of 4—NASA's workhorse in Project Mercury has flown successfully in all its developmental launches, powered by Thiokol solid motors, Pollux, Castor and Recruit. Working as a part of NASA's team, Thiokol has provided top power at low cost. Thiokol means reliability!

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Highly Successful Space Power Systems Conference At Santa Monica Draws Attendance of More than 900

SANTA MONICA, CALIF.—"The best meeting on the subject ever held, and the most rewarding conference of this kind within memory." This comment by one of the attendees at the ARS Space Power Systems Conference, held at the Hotel Miramar here Sept. 27–30, sums up prevailing opinion about the meeting, which drew an audience of more than 900, largest ever for an ARS Specialist Conference.

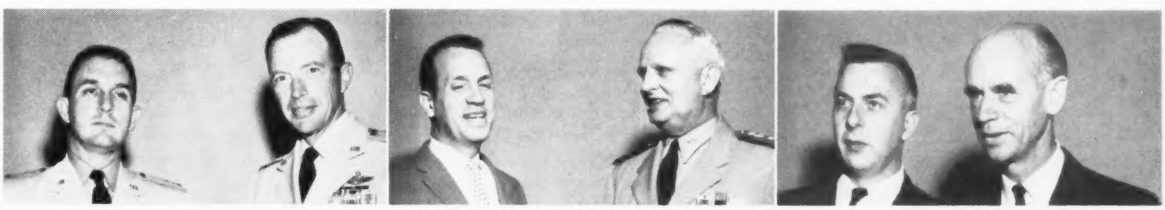
The four-day program, which included eight technical sessions marked by the presentation of some 75 papers, was organized by a high-powered conference committee headed by Walter K. Deacon of Vickers as general chairman and Nathan W. Snyder of IDA as program chairman and appointed by the ARS Power Systems Committee, chaired by Abe M. Zarem of Electro-Optical Systems. Other highlights of the meeting included four luncheons, each addressed by a prominent speaker, and a special exhibit showing recent advances in the space power systems area.

The meeting was planned, in Dr. Snyder's words "to provide scientists and engineers working on power systems with advanced textbook knowledge in a number of fields for which such textbooks have not yet been written." The technical sessions, covering thermoelectricity, thermionics, photovolatic cells, electrochemical cells, solar systems, dynamic engines and plasma generators, systems for nuclear auxiliary power, and application, safety and advanced systems, each began with a review paper and then proceeded to an examination of what has been accomplished to date and the problems which still exist.

Time and again at the conference two subjects came up for discussion—materials and ways and means for increasing powerplant efficiency. Many speakers noted that insufficient knowledge of materials is a common problem in development of all power systems and indicated that, while materials research has been intensified in the past few years, a good deal more remains to be done.

Dr. Snyder, after hearing some of the discussions on powerplant efficiency, commented that, while weight per unit power appears important when there is a weight limitation, and efficiency also appears important because it affects weight, reliability is most important and must be achieved even at the expense of efficiency.

The meeting got under way with a session on thermoelectricity. Papers presented at the session noted that, because of the need for high-temperature heat rejection in space, additional research on high-temperature materials capable of operating in the 800–1200 C range was imperative. Several papers presented at the session dealt with such materials, primarily semiconductors such as cerium sulfide, samarium, thorium, and the silicides, which are capable of operating at high temperatures and are reasonably efficient. One especially interest-



Luncheon toastmasters and speakers. Left to right, Maj. William G. Alexander of the Office of the Director of Research and Development, USAF, and Brig. Gen. John W. Carpenter III, Commander, AF Flight Test Center, Edwards AFB; B. James Wilson, ONR, and Rear Adm. Charles B. Martell, Asst. Chief of Naval Operations for Development; and Kurt Stehling of NASA Hq. and Ernst Stuhlinger of NASA's Marshall Space Flight Center.

Left to right, Nathan W. Snyder, Conference Program Chairman; Abe M. Zarem, Chairman of the ARS Power Systems Committee; and Walter K. Deacon, Conference General Chairman, at press conference.

Special exhibit, highlighting recent space power system developments, was a conference "extra." Here, the Tapco Group exhibit one of the many scientific displays featured at the four-day meeting.

On the calendar

1960	
Nov. 3–4	**ARS and U.S. Naval Postgraduate School Conference on Electrostatic Propulsion, Monterey Calif.**
Nov. 3–4	Ninth Annual Instrumentation Conference of Louisiana Polytechnic Institute, School of Engineering, Ruston, La.
Nov. 7–9	Chemical Engineering Conference and Explosives Technology Session, sponsored by Chemical Institute of Canada, Quebec, P.Q., Canada.
Nov. 15–16	Symposium on Engineering Application of Probability and Random Function Theory, Purdue Univ., Lafayette, Ind.
Nov. 15–16	IRE Professional Group Conference on Product Engineering and Production, Boston Mass.
Nov. 15–17	AF-Navy-Industry Propulsion Systems Lubricants Conference, sponsored by ARDC & Southwest Research Institute, Granada Hotel, San Antonio, Tex.
Nov. 21–26	Colloquium on Space Research sponsored by Argentine National Committee for Space Research and Argentine Interplanetary Society, Buenos Aires, Argentina.
Dec. 5–8	**ARS Annual Meeting and Astronautical Exposition, Shoreham Hotel, Washington, D.C.**
Dec. 13–15	Annual Eastern Joint Computer Conference, Hotel New Yorker and Manhattan Center, New York, N.Y.
1961	
Jan. 9–11	National Symposium on Reliability and Quality Control, co-sponsored by IRE, AIEE, ASQC, EIA, Bellevue-Stratford Hotel, Philadelphia, Pa.
Jan. 16–18	AAS Annual Meeting & Exhibit, Sheraton Hotel, Dallas, Tex.
Feb. 1–3	**ARS Solid Propellant Rocket Conference, Hotel Utah, Salt Lake City, Utah.**
Feb. 1–3	IRE Winter Military Electronics Convention, Biltmore Hotel, Los Angeles.
March 9–10	Symposium on Engineering Aspects of Magnetohydrodynamics, sponsored by AIEE, IAS, and IRE, Univ. of Pennyslvania, Philadelphia, Pa.
March 13–16	**ARS Missile and Space Vehicle Testing Conference, Biltmore Hotel, Los Angeles.**
April 4–6	Symposium on Electromagnetics and Fluid Dynamics of Gaseous Plasma, co-sponsored by Polytechnic Institute of Brooklyn, IRE, IAS, and U.S. Defense Research Agencies, Engineering Societies Building, New York, N.Y.
April 5–7	**ARS Conference on Lifting Re-entry Vehicles: Structures, Materials, and Design, El Mirador Hotel, Palm Springs, Calif.**
April 18–20	Symposium on Chemical Reaction in Lower and Upper Atmospheres, sponsored by Stanford Research Institute, Mark Hopkins Hotel, San Francisco.
April 26–28	**ARS Propellants, Combustion, and Liquid Rockets Conference, Palm Beach Biltmore, Palm Beach, Fla.**
May 9–11	Western Joint Computer Conference, Ambassador Hotel, Los Angeles, Calif.
May 22–24	**ARS National Telemetering Conference, Chicago, Illinois.**
May 22–24	National Symposium on Global Communications, co-sponsored by AIEE and IRE, Hotel Sherman, Chicago, Ill.
May 22–26	Annual Conference of Society of Photographic Scientists and Engineers, Arlington Hotel, Binghamton, N.Y.
June 14–17	**ARS Semi-Annual Meeting, Statler-Hilton Hotel, Los Angeles.**
Aug. 21–23	**ARS International Hypersonics Conference, MIT, Cambridge, Mass.**
Aug. 23–25	**ARS Biennial Gas Dynamics Symposium, Northwestern Univ., Evanston, Ill.**
Aug. 28–Sept. 1	International Heat Transfer Conference, Univ. of Colorado, Boulder, Colo.
Oct. 9–13	**ARS SPACE FLIGHT REPORT TO THE NATION, New York Coliseum, New York, N.Y.**

ing material discussed at the session was gadolinium selenide, which was shown to have a figure of merit approximately 10 times better than other materials in the high-temperature range, and appears to be very promising.

The luncheon speaker that day was Brig. Gen. John W. Carpenter III, Commander, AF Flight Test Center, Edwards AFB, whose topic was "Military Applications of Space Power." Gen. Carpenter noted that a comparison of 1966 forecasts of space power requirements with optimum energy conversion methods as of that date indicates that in most instances no single conversion method will exclusively satisfy any single vehicle category, and that "a comprehensive and aggressive space power research program (is necessary) if the space vehicles projected for the future are to be achieved."

The afternoon session, devoted to thermionics, revealed a sharp increase in understanding of the basic physics involved and of materials. Papers by Melvin Bowman of Los Alamos Scientific Lab on "Chemistry of Fuel Element Materials" (1286–60) and by Robert C. Howard et al. of General Atomics Div. of General Dynamics on "A Nuclear-Thermionic Fuel Element Test" (1287–60) offered an indication of key research now being conducted on the use of thermionics inside nuclear reactors. Some excellent physics research was reported by Karl G. Hernqvist of RCA in his paper "Experimental Research on Plasma Thermionic Energy Converters" (1284–60), which showed a third electrode could be used for ionization purposes, permitting operation of the cathode at lower temperatures than in a diode system.

The session the following morning was devoted to photovoltaic cells. J. F. Elliott et al. of GE, in a paper on "Thin Film Silicon Solar Cells" (1290–60), reported research which indicates the possibility of developing large-area thin-film cells and producing solar cells with a higher power output. The paper on "Some Theoretical Aspects of the Physics of Solar Cells" (1293–60) by Hans Queisser and William Shockley of Shockley Transistor Corp. showed a good understanding of the basic physics involved, while R. M. Downing and J. M. Denney of STL revealed in their papers (1294– and 1295–60) some important research on solar-cell radiation damage. Dr. Denney's paper reported significant findings on radiation effects on Explorer VI solar cells.

These findings were emphasized in an Army release the same day indicating that the Army Signal R&D Labo-

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80 cu. in. bottle for storage of concentrated sulphuric acid. 5 in. dia., weight 1 lb. including Teflon liner wound into structure. 150 psi operating pressure, 300 psi proof, 750 psi min. burst. Minimum life of 1000 operating cycles from 0 to 150 psi. Leakage guaranteed less than MIL-R-8573A.

2700 cu. in. bottle for nitrogen storage in space satellite. 2 ft. long, 13 in. dia., weight 31 lbs. including fittings. 3000 psi operating pressure, 3750 psi proof, 6000 psi min. burst after life of at least 400 operating cycles from 0 to 3000 psi. Leakage guaranteed less than MIL-R-8573A.

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MATERIAL	DENSITY lbs/cu. in.	TENSILE STRENGTH psi	STRENGTH/WEIGHT in. x 10^6
Aluminum	.097	80,000	.83
Titanium	.163	160,000	.98
Highly Heat Treated Steel	.283	240,000	.85
HYSTRAN	**.072**	**165,000***	**2.29**

*Biaxially stressed hoop tension

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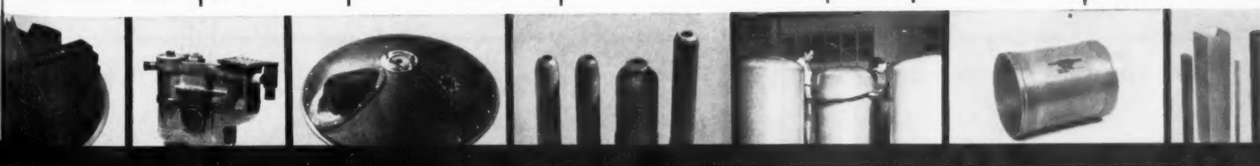


ratory, in cooperation with RCA, had developed a new solar cell from 10 to 40 times more resistant to electron radiation damage than previous cells.

Luncheon speaker that day was Ernst Stuhlinger, Director of Research Projects, NASA Marshall Space Flight Center, whose topic was "Long-Range Space Power Requirements." In his talk, Dr. Stuhlinger anticipated the following requirements for space power in the future: 1961, 1–3 kw; 1964, 30–60 kw; 1968, 300–1000 kw; and 1970–75, 10–20 mw. He estimated that power requirements for the next five years would be met, but was somewhat less optimistic about the 10 years beyond that.

The afternoon session, on electrochemical cells, revealed significant scientific advances in the understanding of the photochemistry of fuel cells. In other papers presented at the session, Irwin M. Schulman of GE-MSVD (1307-60) and U.B. Thomas of Bell Labs (1308-60) gave important information on sealed nickel-cadmium batteries for space vehicles, while J. S. Bone and M. D. Read of GE-MSVD, in 1305-60, reported on new data relative to a sealed, regenerative H_2-O_2 fuel cell without moving parts which may be useful in various space applications.

The solar-systems session the following morning included a panel discussion, moderated by Dr. Snyder, on solar cell-storage battery systems developed for U.S. space vehicles, covering all present and near-future vehicles, and revealing an outstanding improvement in such systems over the past two years. Also of interest at this session was a paper (1314-60) by Donald H. McClelland of Electro-Optical Systems dealing with lightweight, highly accurate mirrors for space applications.

The luncheon speaker was Rear Adm. Charles B. Martell, Asst. Chief of Naval Operations for Development, who discussed "Power Parameters." A tantalizing hint of an intriguing effort in this area was provided by Adm. Martell in a brief mention of the "bug battery," a classified Navy research project in which bacteria of given characteristics are used to aid polarization and thus improve the efficiency of electrolytic cells.

The afternoon session, devoted to dynamic engines and plasma generators, revealed that the development of high-speed mercury-vapor turbomachinery is quite in advance of turbine technology of two or three years ago, and that there are still many new ideas in a relatively old field. The paper by Ken Johnson of Aerojet-General Nucleonics on "Dynamic Versus Direct Conversion" (1321–60) indicated that it is as yet not quite clear that thermionics, even if developed, would be better than turbomachinery from the weight and reliability standpoint.

Both sessions on the last day of the meeting were largely devoted to an examination of the AEC Snap program, carried out under the direction of the AF Aircraft Reactors Branch. At this, the first full-scale rundown on the five years of research conducted under the program, it was clearly indicated that it will be possible to build small, compact and safe reactors for space vehicles. Papers presented at the sessions indicated that individual problems still remain, but most authors were optimistic about the future.

The luncheon speaker the final day was Chauncey Starr, vice-president of North American Aviation and president of the company's Atomics International Div., who discussed "Industry's Role in Space Technology." In his address, he noted that the astronautics field today places major importance on R&D, rather than production, and that this changed objective

Bound Volumes of ARS Publications Available

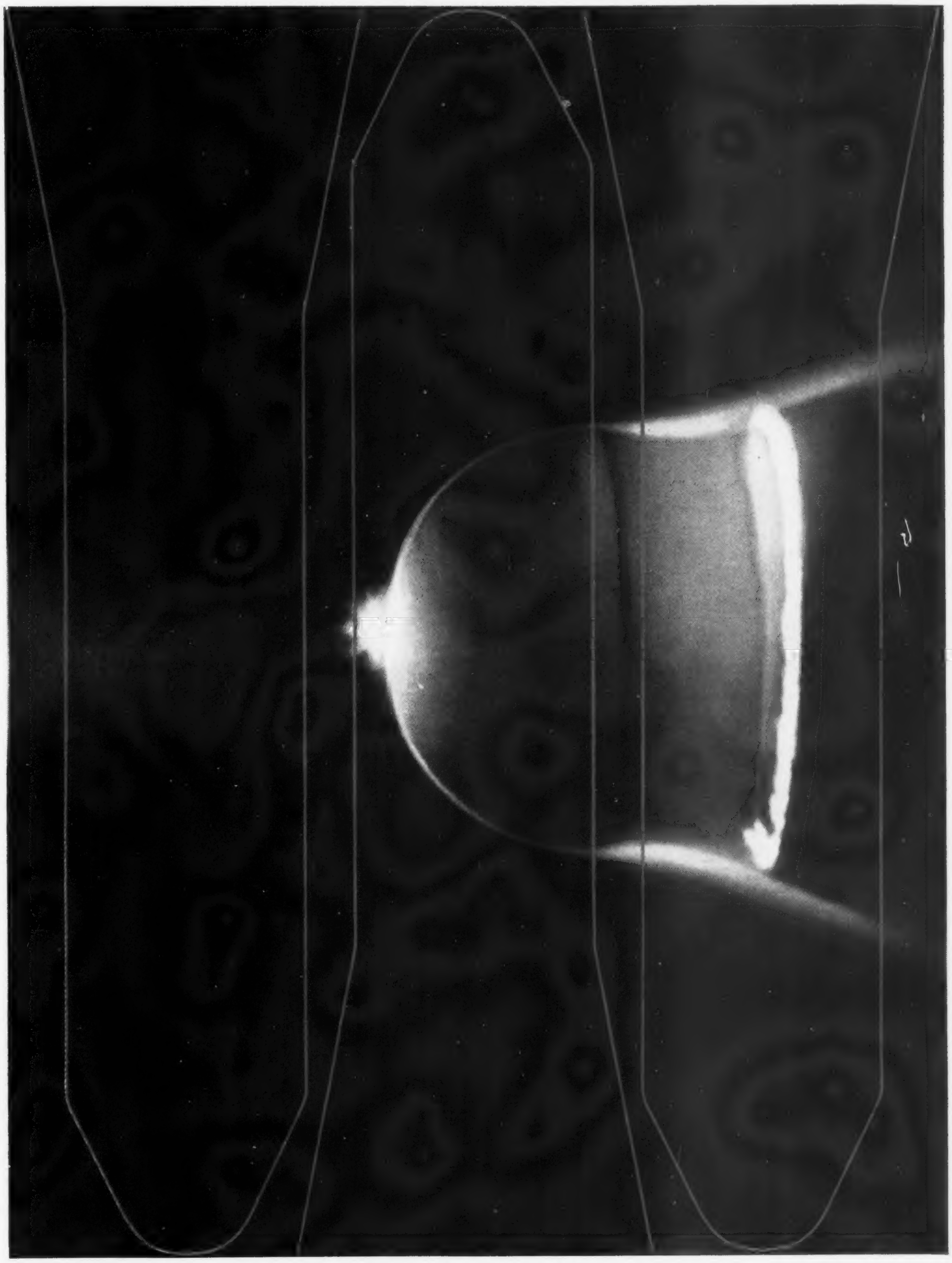
Bound volumes of the 1958 and 1959 issues of *Astronautics* and *ARS Journal* are now available in limited quantities from ARS Headquarters. The volumes, covering the complete year, are bound in buckram and stamped in gold lettering, and include a separate index.

Since the quantities are limited, the volumes are being offered on a first-come, first-served basis. Prices are $20 each for the 1958 and 1959 volumes of *Astronautics*, and $25 each for the 1958 and 1959 volumes of *ARS Journal*. Orders, accompanied by check or money order, should be addressed to Dept. B, AMERICAN ROCKET SOCIETY, 500 Fifth Ave., New York 36, N.Y.

1960-61 ARS Meeting Schedule

Date	Meeting	Location	Abstract Deadline
Nov. 3–4	Electrostatic Propulsion Conference	Monterey, Calif.	Past
Dec. 5–8	ARS Annual Meeting and Astronautical Exposition	Washington, D.C.	Past
1961			
Feb. 1–3	Solid Propellant Rocket Conference	Salt Lake City, Utah	Past
March 13–16	Missile and Space Vehicle Testing Conference	Los Angeles, Calif.	Past
April 5–7	Lifting Re-entry Vehicles: Structures, Materials, and Design Conference	Palm Springs, Calif.	Past
April 26–28	Propellants, Combustion, and Liquid Rockets Conference	Palm Beach, Fla.	Nov. 28
May 22–24	National Telemetering Conference	Chicago, Ill.	Dec. 15
June 14–17	ARS Semi-Annual Meeting	Los Angeles, Calif.	Feb. 1
Aug. 21–23	International Hypersonics Conference	Cambridge, Mass.	Jan. 15
Aug. 23–25	Biennial Gas Dynamics Symposium	Evanston, Ill	Jan. 15
Oct. 9–13	ARS SPACE FLIGHT REPORT TO THE NATION	New York, N.Y.	May 2

Send all abstracts to Meetings Manager, ARS, 500 Fifth Ave., New York 36, N.Y.



Blasting new materials to make missile nose cones. The first ICBM nose cone ever to be recovered after flight was protected by a new, high-temperature material. Its name: Avcoite. Its construction: specially reinforced ceramic. Avcoite was the first of a family of new heat-shielding materials. They were developed for re-entering nose cones and satellites by Avco's Research and Advanced Development Division. Newest addition to this materials family is Avcoat, a plastic heat-shield here ablating smoothly in a hydrogen-oxygen jet simulating satellite re-entry temperatures.

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requires a re-assessment of the proper role of industry. Only by a clear demonstration of its competence, efficiency, and integrity can industry meet its responsibility for the nation's space program, he added.

The scope of the program, the comments of those in attendance, and the continuing round of informal discussions which marked the meeting all attested to its high quality. It has set a standard for future conferences of this type.

—**Irwin Hersey**

German Rocket Society Holds 9th Annual Meeting

Left to right, A. Ehmert, A. F. Staats, president of the German Rocket Society, and Dr. and Mrs. Wolfgang B. Klemperer, Douglas Aircraft, pose at the Hanover meeting.

HANOVER, WEST GERMANY—An ARS delegation took the opportunity presented by the IAF Congress in Stockholm in August to continue to this city for the 9th Annual Meeting of the German Rocket Society, held August 26–28. The meeting attracted a total attendance of 500 and witnessed the presentation of a number of technical papers, including several by U.S. delegates.

Of particular interest was a paper by J. M. J. Kooy of the Netherlands on the perturbing influence of the sun on possible Mercurian or Venusian satellites. Prof. Kooy feels the influence of the sun is strong enough to perturb these satellite orbits to a point where the satellites either collide with their planets or are torn away from orbit and proceed on a hyperbolic path into space.

A paper by S. G. X. L. Fonseca of Portugal described the application of artificial planetoids for manned space exploration. Basing his paper on a Nova-type booster, he proposed the use of circumsolar planetoids as refueling stations for interplanetary vehicles, thus reducing the thrust requirement for such vehicles to about one-fifth that required for making such journeys without refueling.

The program for the meeting was planned by A. F. Staats, president of the German society, and was of great value to American participants since it provided them with an opportunity to make contacts with top members of the rapidly expanding German rocket industry.

—**John B. Gustavson**
Grand Central Rocket Co.

Telemetering Conference Abstracts Due Dec. 15

Abstracts of papers for the 1961 National Telemetering Conference, to be held May 22–24 at the Sheraton Towers Hotel in Chicago, must be submitted to Program Chairman Jack Becker of AC Spark Plug Div. of General Motors, Milwaukee 1, Wis., by December 15.

Theme of the 1961 Conference, cosponsored by ARS, AIEE, IAS, IRE, and ISA, and hosted by IAS, is "Science and Education in Telemetry." Tentative technical session titles are: Telemetry standards (workshop), transducers, space data acquisition systems, data processing and presentation, signal conditioning, bio-medical telemetering, PCM systems, telemetry education in the '60's (workshop), environmental measurements, underwater measurements, RF components and techniques, flight-test data systems, transistorization progress, and industrial data transmission. Five papers are being sought for each technical session.

Papers will be selected and the technical program finalized by January 15. All papers must be received by March 1 for publication prior to the conference.

SECTION NEWS

Antelope Valley: at the September meeting, guest speaker ARS Vice-President **Harold W. Ritchey** of Thiokol Chemical Corp. discussed "The Future Role of Solid- and Liquid-Propellant Systems." The talk covered the various important parameters, performances, and costs of solid and liquid systems presently obtainable and, by applying these factors, how to determine which system should be used for future missions. The meeting was well attended (approximately 70 persons) and a question-and-answer session was held after the talk.

The board of directors and officers of the ARS Section had a dinner meeting with Geoffrey Potter, ARS membership manager, on September 21, to discuss problems locally and nationally.

—**Leslie O. Harrington**

Central Colorado: Space travel and exploration of the planets should bring a world renaissance in science and art, according to ARS President **Howard Seifert,** who addressed the Section at the annual president's dinner in September, preceded by a reception sponsored by the Martin Co.

Dr. Seifert stressed that tremendous benefits are just around the corner in space exploration.

"Such things as weather satellites and global television will bring tremendous sociological changes to the world," he said. "Consider sitting in your living room and watching a Russian peasant family on TV. Throughout history whenever methods of communication and transportation moved forward, the entire civilization underwent an adjustment. This undoubtedly will be true in the immediate future, although we cannot begin to see all of the benefits which space exploration ultimately will bring."

Dr. Seifert also discussed difficulties encountered in setting up and carrying out a crash program in ICBM development.

"This crash program," he said, "may have cost four or five times what it would have if we could have taken 10

Howard Seifert, ARS President

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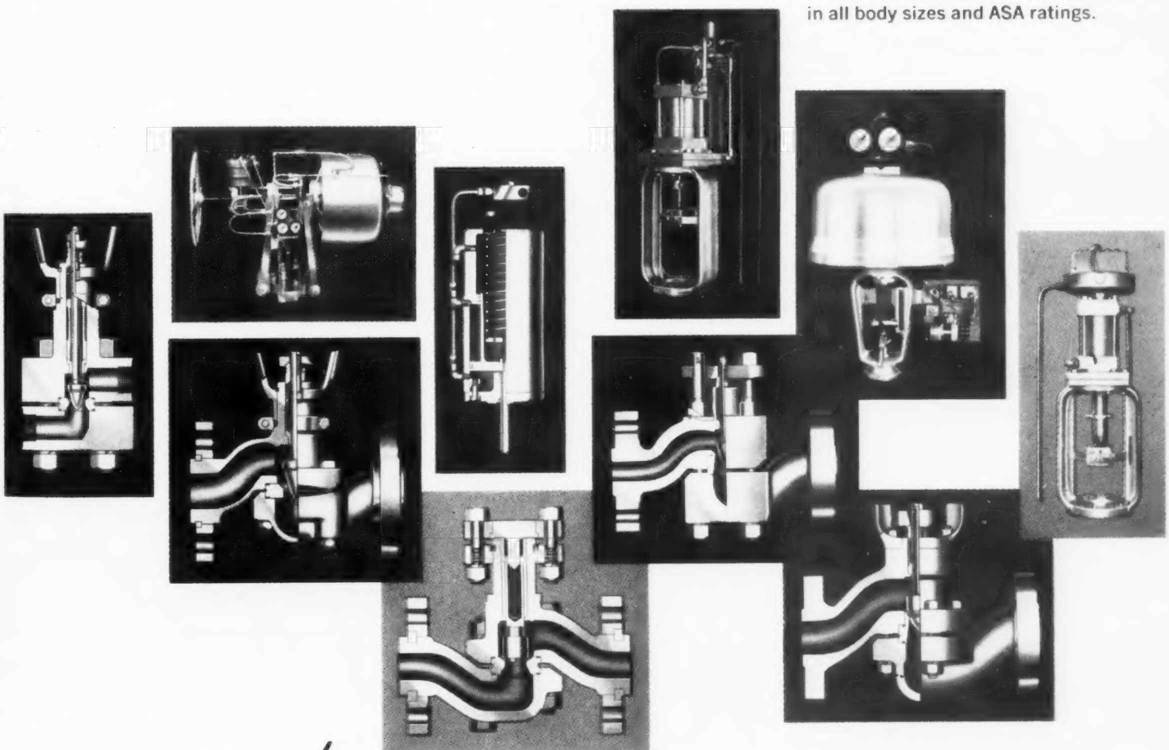

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years for it. The development probably will cost $3 billion, but I think we can be happy about it." He pointed out that most of the ICBM cost (75 per cent) is going into ground-based facilities and handling equipment, rather than flight hardware. Developing a completely new weapon system in six years, rather than 10, according to Dr. Seifert, was comparable to giving an order in the year 1700 to create a railway system through the wilderness of America.

"I doubt if the United States will ever have another crash program such as the ICBM development," he said. "It's hard to see how the country could be marshalled behind another such program."

But he suggested that if there ever be another crash program, it may occur in the field of education. Some educators have proposed automation in schools, particularly in primary education where typical problems could be programmed into a computer, which in turn could diagnose learning problems of individual youngsters.

—**Henry Still**

Central Texas: The April 1960, meeting, held at Baylor Univ., Waco, Tex., with 50 members present, heard guest **R. B. Dillaway,** manager of nucleonics for Rocketdyne, discuss the role of non-chemical propulsion in space—ion and plasma principles and state of the art of the various design possibilities.

The next meeting, in August, held at the Ridgewood Country Club, Waco, with 55 members present, heard **John F. Tormey,** chief engineer for Rocketdyne's Solid Propellant Operations, McGregor, Tex., discuss the present position of Rocketdyne in the solid-propellant industry.

—**F. R. Gessner Jr.**

Columbus: The first meeting of the fall season was held at Ohio State Univ. on September 13 with guest speaker **R. F. Meyer,** assistant technical manager of the Polaris propulsion system, outlining the Polaris development program from 1956 to the present. He dealt primarily with problems associated with propellants, but he also gave a lucid description of the complete weapon system, its demands on propulsion, and the success that has been obtained in satisfying the design requirements. Meyer also explained that the present Polaris is a 1200-mi vehicle called the "Intermediate Tactical" and that the 1500-mi missile, the "Tactical" unit, will be in production soon.

Meyer also showed motion pictures of the Aerojet facility, the compounding of fuels, test firings, and a recent successful firing from a submerged submarine.

—**William L. Buckel**

Northern California: The Section enjoyed a field trip at the Santa Cruz Test Base of the Lockheed Missiles and Space Div. in August. The tour of the base included a visit to the Polaris "soft" test stand, in which a complete missile can be essentially flown through a trajectory by varying the tension on arms which hold it in position. A complete description of the instrumentation in the control building was also provided so the operation of the test and recording of the "flight data" could be understood. The tour continued by visiting a remote section of the base where a spe-

Where You See the Rough Ones

Members of the Northern California Section on a field trip to the Santa Cruz Test Base of the Lockheed Missiles and Space Div. gather on a hillock to watch from a safe distance the destructive firing of a large solid-propellant motor with a weakened casing.

American Rocket Society

500 Fifth Avenue, New York 36, N. Y.

Founded 1930

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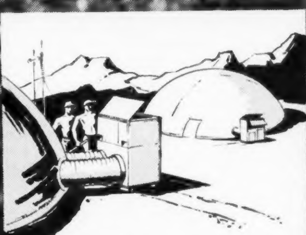

Inflatable shelter refrigeration unit, 7½ tons capacity (unit shown above)

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The compact, fully automatic unit shown at left, for example, measures 5x5x2 ft, weighs only 550 lb and provides 7½ to 10 tons of cooling on a 125°F day. It also provides 90,000 Btu per hour heating.

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Essentially the same AiResearch air conditioning system used in today's jet airliners, these lightweight units have more than 500,000 hours of proven dependability.

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Now You Take Solids, Now You Take Liquids

R. B. Canright (center), chief of the NASA Saturn Office, Washington, D.C., briefs panel members before a classified seminar on solid- and liquid-propulsion units conducted recently by the ARS Alabama Section, Redstone Arsenal. The panel members, left to right are: R. H. Wall, Thiokol Chemical Redstone Div.; Terrell Jones, Amcel Propulsion, Inc.; Canright; D. M. Hammack, Structures and Mechanics Div. of NASA's Marshall Space Flight Center at Huntsville; and D. W. Hege, Rocketdyne.

Atlanta Section Forming

ARS members meeting to discuss the formation of a new Section in the booming city of Atlanta, Ga. F. A. Cleveland, a director, stands and makes a point; at his immediate left, J. D. Turci, vice-president, and R. B. Ormsby Jr., president.

PMR Guests Discuss Navy Space Effort

Capt. Hayden L. Leon, USN, Commander of the Naval Air Development Command, Johnsville, Pa., and Capt. Robert F. Freitag, USN, Astronautics Officer of the Bureau of Naval Weapons, Washington, D.C., discussed progress and plans in the Navy space effort recently as guests of the ARS Pacific Missile Range Section in a meeting held at Pt. Mugu, Calif. Above, from left, Capt. W. E. Sweeney, USN, Deputy Commander of PMR; Dr. H. Krutter, Chief Scientist of NADC, Johnsville, Pa.; Lyman E. Wood, PMR Section president; and Capt. Leon and Capt. Freitag.

cial test motor, whose case had been purposely weakened, was fired. The firing was quite spectacular in that the weakened case ruptured, permitting propellant to burn through both the nozzle and the rupture.

—Howard Kindsvater

Pacific Missile Range: One hundred members of the 138-man PMR Section held a luncheon meeting in August in the Officers' Club at the Naval Missile Center, Point Mugu, Calif. **Capt. Hayden L. Leon,** USN, who commands the Naval Air Development Center at Johnsville, Pa., discussed the work of his organization. He also described his attendance at one of the earliest American missile launches conducted by Dr. Goddard.

The other speaker was **Capt. Robert F. Freitag,** USN, Astronautics Officer of the Bureau of Naval Weapons. His subject was the rationale of Navy space efforts. He stressed the practicality that characterizes the Navy's space programs in the fields of navigation, communication, and weather satellites, which should provide economical services which would cost vastly more if established as terrestrial systems. The field of space surveillance is also receiving strong attention from the Navy, he said. **H. Krutter,** chief scientist at Johnsville, also attended the meeting.

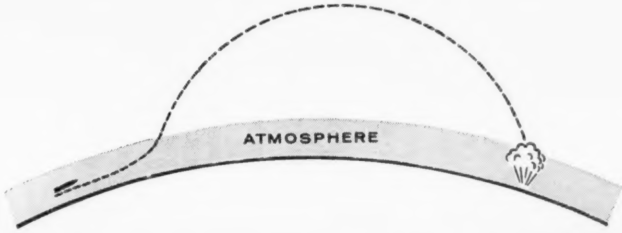
The Section held a luncheon meeting in September with 40 members present to hear two local speakers discuss their specialties.

Willard Waite of the Optical Development Div. described the growth of demands for photographic tracking since the days of the Loon missile and outlined the progress that has been made not only in cameras, lenses, and mounts but also in automatic methods of tracking by radar and infrared to extreme distances.

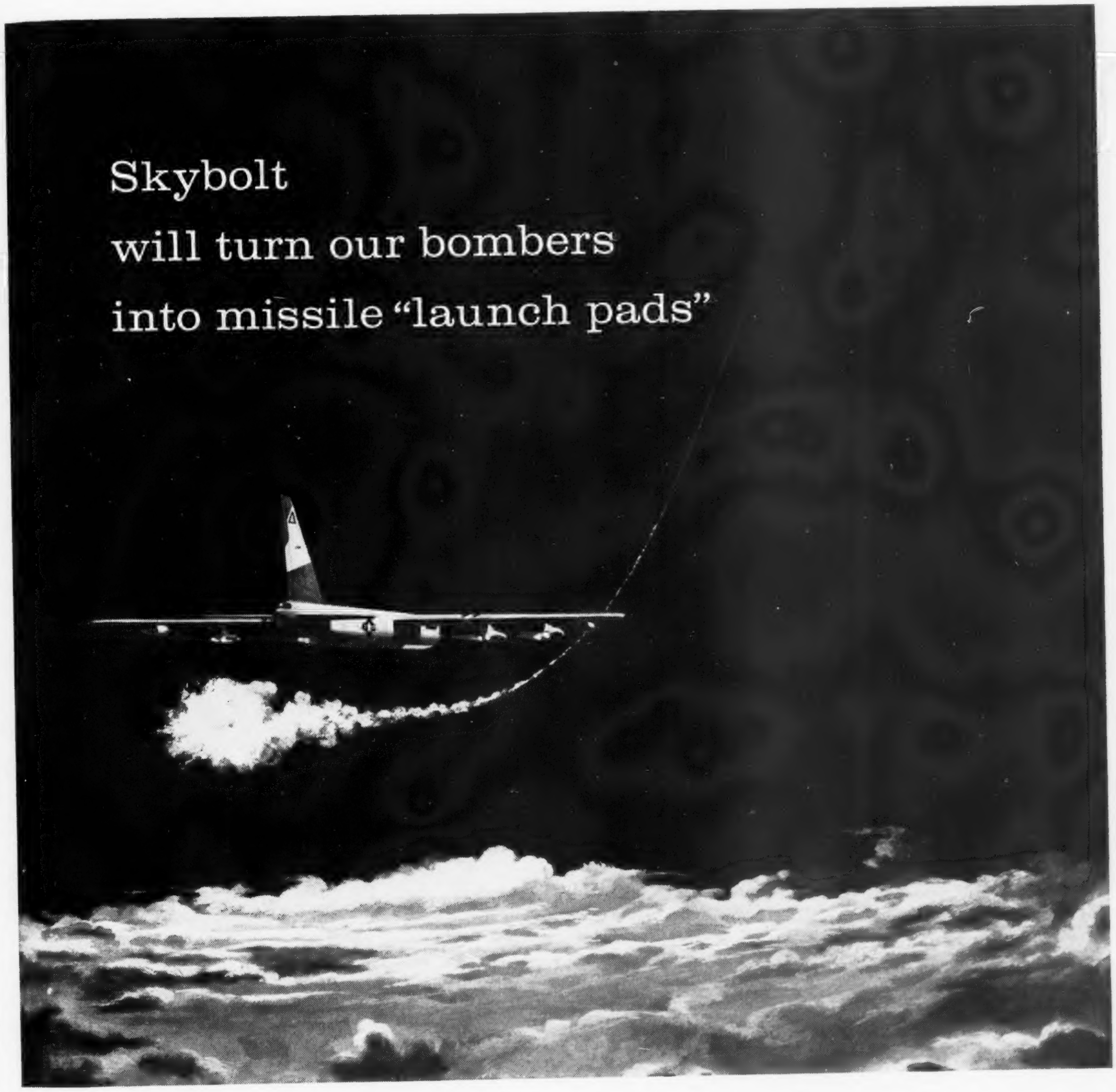
Comdr. J. J. Pace, USN, Technical Planning and Program Coordinator in the Range Affairs Office, gave a lecture on technical capabilities of the Range, as based on present and currently predictable program requirements. He stressed the basic philosophies of mobility, use of existing support facilities, and coordination with other ranges. These concepts, as applied to current range problems and future expansion, were fully illustrated with pertinent slides.

—Arthur Menken

Princeton. The following officers have been elected to head the Section: Sidney Sternberg of RCA Astro-Electronic Products Div., president; David T. Harrje of Princeton Univ., vice-president; and Herman Gurin of RCA Astro-Electronic Products, secretary-treasurer. ♦♦



When operational, Skybolt ballistic missiles could ring an enemy with sure retaliation . . . and make any aggressor think twice.



Nineteen years of Douglas experience with military and space-research missiles is wrapped up in the Air Force's new Skybolt GAM-87A—an air-launched hypersonic ballistic missile now under development.

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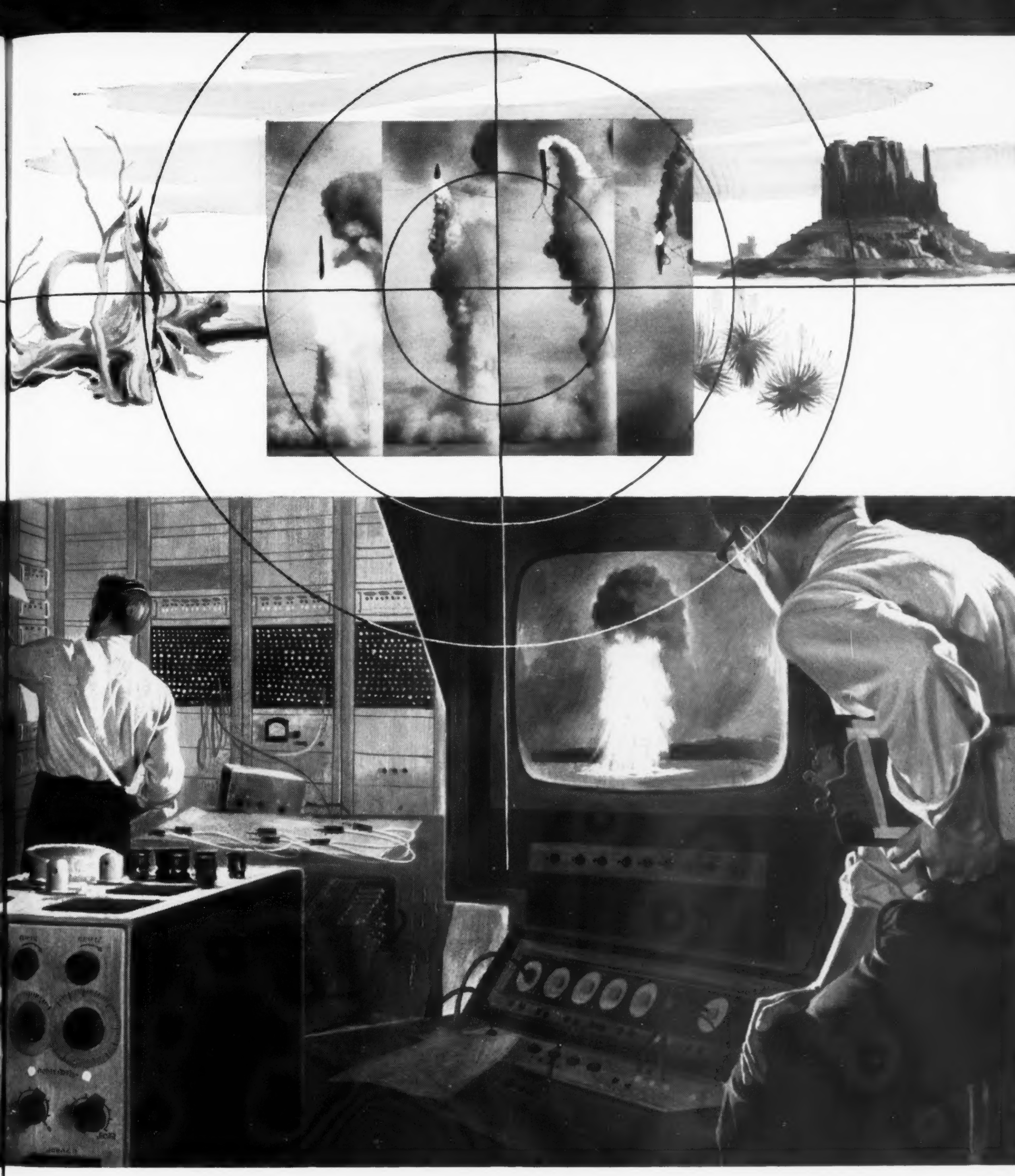

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Electrical Propulsion

(CONTINUED FROM PAGE 33)

ature of the gas in the chamber is of the order of 3000 to 12,000 K (4). The walls, if properly cooled, can be held safely below the melting point. The exhaust velocity for the nozzle is equal to $\sqrt{2\Delta H}$ where $\Delta\ H$ denotes that part of the enthalpy of the gas that transforms into kinetic energy of the beam.

The enthalpies must be carefully compared at the high chamber temperatures before propellants can be appraised. Hydrogen motors have been operated successfully over extended periods with an exhaust velocity of 10–11 km/sec (I_{sp} = 1000–1100 sec) at chamber temperatures of about 3000 K (5). At higher temperatures, *Li* or *LiH* may be preferable. The merit of a propellant is determined by its available enthalpy at the chamber temperature, by its cooling capabilities, and by its storability.

It is anticipated that exhaust velocities up to 15 km/sec (I_{sp} = 1500 sec) may be obtained within a few years. The limit for arc-heated systems appears to be around 20–25 km/sec (I_{sp} = 2000–2500 sec) (6). One reason for this limit is the high conductivity of the chamber gas at high temperatures. When this conductivity approaches that of copper, ohmic losses in the external circuit reduce the overall efficiency of the system considerably. Typical figures of present efficiencies are 50–55 per cent; 61 per cent has been reported by one group (7).

One of the advantages of electrothermal propulsion is the easy controllability of exhaust velocity. Within fairly wide limits, power consumption of the engine is independent of the rate of propellant mass flow. Greater mass flow rate means lower average temperature, and therefore lower exhaust velocity, but greater thrust. It should therefore be possible to build arc-heated engines with variable propellant flow.

One of the most stringent problems arising with the long-time operation of arc-heated systems is electrode erosion. Promising methods to overcome this danger are under development. Operating times of several hundred hours at exhaust velocities of 10 km/sec (I_{sp} = 1000 sec) and a thrust of one-tenth to one-half lb per chamber may be available soon.

In the field of electrostatic propulsion, the past year has produced advances in performance and technique and a concentration of effort upon clearly defined objectives, with the promise that determined efforts toward significant demonstrations of thrust will be made during the coming year.

Ion sources which make use of the thermal contact ionization of alkali metals are in the most advanced state. Cesium is the alkali almost universally used in current programs because it permits higher voltage and larger electrode spacings to be employed for a given specific impulse and thrust. Successful demonstration of two means of feeding cesium atoms to an ionizing surface have been made. In one, the cesium emerges from orifices in front and to the side of the hot tungsten surface (8). The atomic beam is collimated so as to minimize diffusion of cesium to areas other than the emitter. One hundred and fifty milliamps at 20,000 volts has been reported, the propellant utilization efficiency being 50 per cent. The other system makes use of porous tungsten (9–12), the feed being from the rear. Thirty-five milliamps at 2000 volts has been reported. The loss of cesium in the form of neutrals is difficult to measure, but is well below 10 per cent (12).

Power radiation from the front side of the tungsten is 5–10 watts/cm^2. In order not to exceed optimum specific impulse, the accelerating voltage must be limited to a few thousand volts. Current densities of many milliamps/cm^2 will therefore be essential if reasonable efficiency is to be achieved. Space charge laws then dictate that spacings must be at most a few millimeters. For reasonable thrust (e.g., several millipounds) the effective diameter of the total accelerated ion beam must be 20–100 times greater than this spacing. The quest for high efficiency will make the ion engine small (13). Because of the limitations of ion optical focusing systems, there must be several hundred exit orifices per millipound of thrust (13). If lined up in two-dimensional cylindrical geometry, a total length of exit slit several hundred times its width is essential for each millipound of thrust.

Highly encouraging performance of ion optical focusing systems were achieved during the year, one group reporting 99.9 per cent transmission (14), and another 99.99 per cent transmission. Both used cesium ions from porous emitters (15). The implications for life are encouraging. The mass of material eroded away by sputtering will be roughly equal to the mass intercepted by the focusing electrodes at values of I_{sp} of near-term interest, and will thus be negligible in comparison to the throughput of propellant.

The essential neutralization of the ion current and the ion space charge

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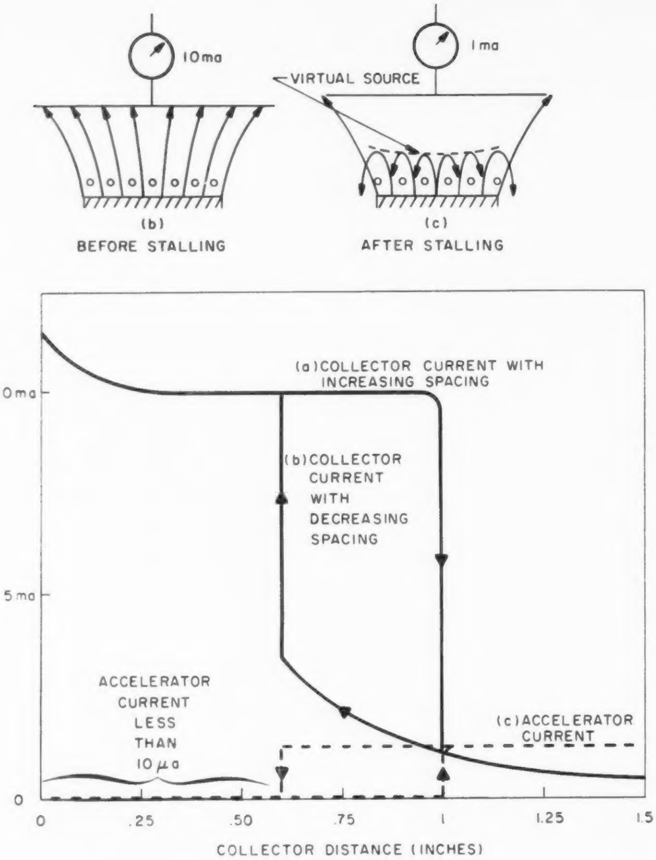
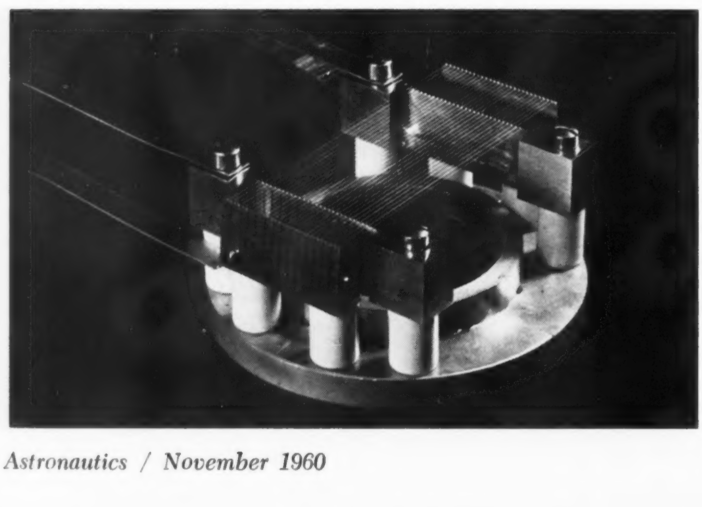


"Ion turn-around" is demonstrated in this TRW experiment. Cesium ions from a 1-in.-diam porous-tungsten plug at $V = +1000$v focus through a wire grid at a distance of 2 mm. The collector electrode is at the same potential as the grid ($V = 0$) but the presence of positive ions causes a positive (decelerating) potential to build up in the intervening space. If the beam is sufficiently broad the ions stall when the spacing becomes too large, most of them returning to the grid or the source. Neutralization of a broad beam by addition of electrons, so that the ions will move into space without appreciable loss of velocity, is a principal outstanding problem in electrostatic propulsion. Below, a 99.9 per cent ion-accelerating system of the type that produced the turn-around effect; grid wires are 1 mm apart (Ref. 14).



by addition of electrons has been a principal subject of study, but reports are still inconclusive. The simpler theoretical analyses require that the electrons move at the same speed as the ions (16). For 2000 volts ion energy, the electrons would have kinetic energy of less than 0.01 volt, (corresponding to a temperature of only 110 K), and the neutralized beam would have to be equi-potential throughout its volume to better than one part in 100,000. Both these conditions are rigorous in the extreme.

A more realistic model pictures a randomly moving cloud of fast electrons having a net drift velocity which matches that of the ions. The circulating electron current in this case would be many times higher than the ion current. It is difficult to imagine how the random motion of the electrons can be established sufficiently rapidly in an ion thrust beam. If the beam is not neutralized within a distance about equal to its acceleration distance (i.e., a few millimeters), it will "stall," with reflection of some of the ions back to the source. The mean free paths and relaxation lengths in a practical beam are, however, of the order of tens of hundreds of centimeters.

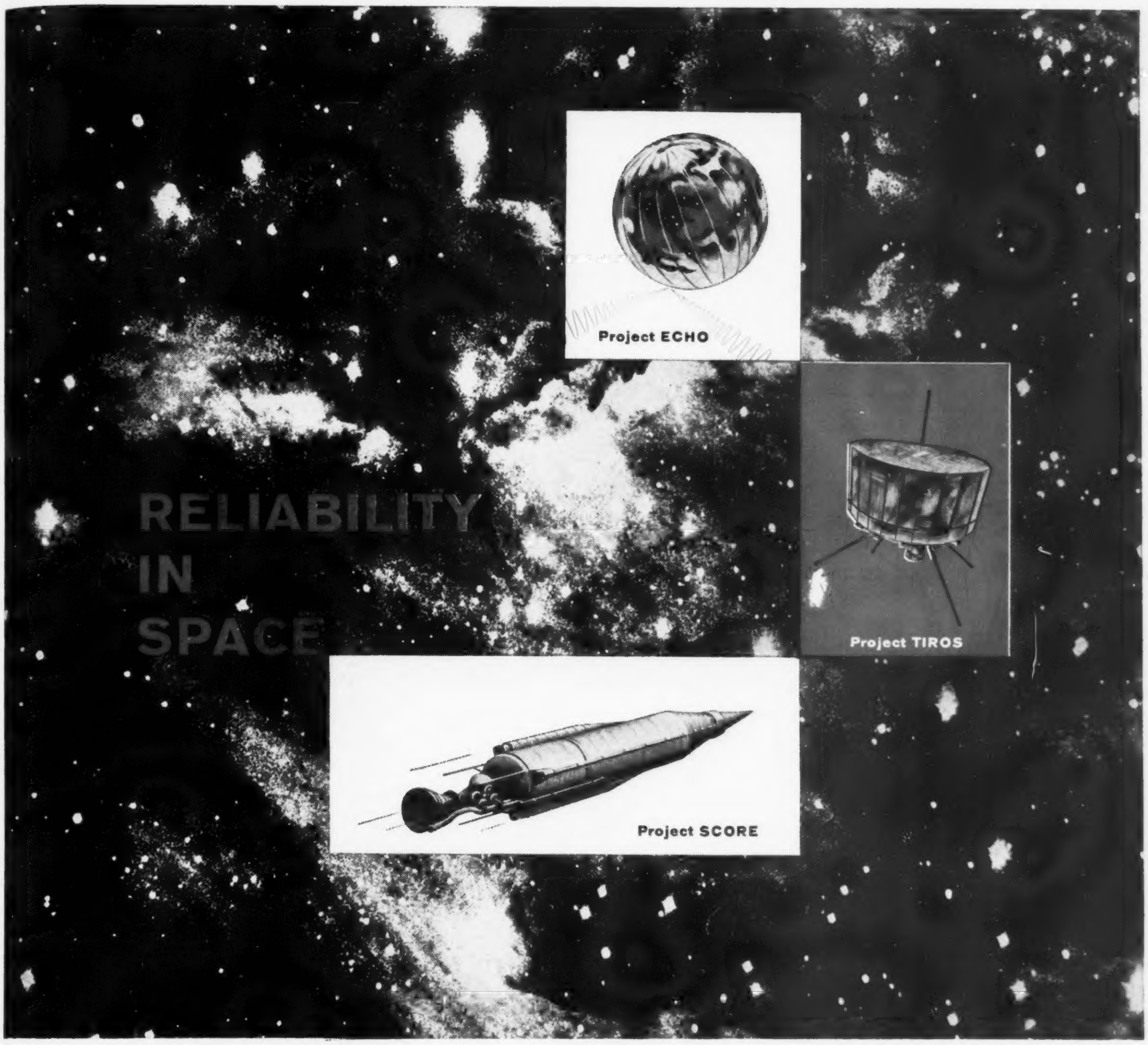
Toward Neutral Beams

It is important to note that neutralized cesium ion beams have been produced in many laboratories, and that some of these have been broad, high perveance beams. Analyses of transient electron trapping effects have led one group, however, to ascribe their apparent success to the influence of background gas pressure and finite volume of the container, conditions which would not exist in space (14).

An interesting experiment has been reported (15) in which ordered motion of electrons transverse to the direction of ion motion was established by carefully designed focusing electrodes, resulting in apparent elimination of net positive space charge as measured by the spreading of the ion beam.

It appears that successful electrostatic propulsion depends upon solution of the neutralization problem, and that the field awaits a decisive experiment.

Mention should also be made of interesting lines of research of longer term nature. First, gaseous discharges for ion sources are believed by their proponents to be capable of producing ions as effectively as surface ionization sources using alkalis. The duoplasmatron (17), a promising embodiment of this viewpoint, is under investiga-



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April, 1960: TIROS I. The sophisticated satellite, including its structural design as well as the electronic systems, and its ground stations were developed and built for NASA by AED under the technical direction of the U.S. Army Signal Corps. It accomplished its mission in meteorological observation, sending down over 20,000 TV pictures of earth and its cloud cover.

August, 1960: Project ECHO. The only electronic equipment on this 100-foot balloon, launched by NASA to prove the feasibility of passive communications satellites, are two "dinner plate" beacon transmitters 10 inches across by 3/8 inch thick, including storage batteries and solar cells. These units, designed to permit beacon tracking of the satellite, weigh only 11 ounces apiece and were developed and built by AED.

As more and more sophisticated space systems are developed, AED will continue to design for reliability in this most demanding of all environments. To find out how you can draw on this dependable R&D capability, contact the Manager, Marketing, RCA Astro-Electronics Division. If you are interested in participating in this challenging team effort, contact the Employment Manager, Astro-Electronics Division, Defense Electronics Products, at RCA's "Space Center" in Princeton, N. J.

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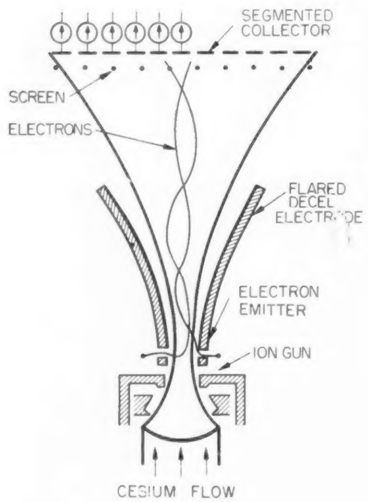
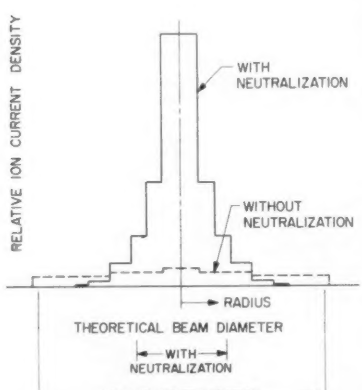
tion at a number of laboratories, but few definitive data have yet been published. Second, particles much heavier than elemental ions are under study for use as propellant (18–20). Accelerating potentials of one million or more volts would be required, and charge-to-mass ratios close to the limits set by surface field strength considerations and by ultimate tensile strength would be needed. Detailed statistics have been reported for octoil (20) and Wood's Metal (21), the latter yielding values up to 80 coulombs/kg. This would give an $I_{sp} = 1200$ sec at 10^6 volts. Problems of adequate uniformity and mass flow remain to be solved. Third, the possibility of using beams of negative and positive ions in parallel has been proposed (21). The approximate equality of masses would eliminate the neutralization difficulties associated with the extremely light weight of the electrons. The possibility of producing a copious and efficient source of negative ions is therefore a novel subject of much current interest.



Diagrams represent Hughes Research Laboratories experiments in beam neutralization. Above, the ion beam (funnel area) diverges owing to mutual repulsion of ions, but does not "stall." The electrons are drawn so rapidly down the beam that they do not effectively neutralize. The diagram below, representing current distribution in a beam with a redesigned neutralization chamber, indicates that the addition of electrons significantly reduces beam spread (Ref. 15).



In contrast to the electrostatic forces and charged propellant employed in the ion engine, plasma propulsion devices are characterized by the use of electromagnetic fields to accelerate a macroscopically neutral plasma. Plasma acceleration relies on the fact that currents can be produced in an ionized gas, which can then interact with a magnetic field to produce a body force.

Existing plasma-propulsion devices generally fall into one of two broad categories, those employing electrodes and those without electrodes. The relative merits of these two techniques is one of the important and currently undecided questions of plasma propulsion. Whereas electrodes and arc heating entail problems of electrode erosion and heat transfer (22) and raise questions of reliability, they provide a simple method for producing a highly conducting plasma. Electrodeless devices, on the other hand, face problems of obtaining a plasma of sufficiently high conductivity, particularly at lower specific impulses, and require somewhat more complex electrical circuitry.

One of the simplest of the devices employing arc discharges is the rail gun (23). In this device, the plasma is used to short-circuit two conducting rails and is forced down the rails by the magnetic field produced by the current through the rails and plasma. This device can be seen to be related to the series-wound motor, in which the same current flows through both field coils and armature, with the connection being made by brushes and commutator or, in this case, by the contact between the rails and plasma.

A number of interesting variations on the rail gun have been produced, including coaxial shock tubes (24,25) and the pinch engine (26). These devices employ a concentric geometry, with the plasma distributed in the annular region between the conducting walls. The current travels down the outside wall, through the plasma, and returns along the inside wall. In the annular shock tube, the plasma is pushed forward by the expanding current loop, setting up a shock wave. The gas between the electrode walls is then shock-heated and moves in front of the current loop, providing an increased momentum primarily through a build-up of the mass of moving gas. Experiments with this apparatus have provided plasma velocities corresponding to specific impulses of 10,000–20,000 sec. Experiments were also conducted in which only a small amount of gas is injected at the end of the tube and increased momentum is obtained by accelerating the fixed mass of plasma. The pinch engine differs somewhat from these devices in that specially shaped electrodes are employed to convert motion of a radially pinched gas to axial motion through a nozzle.

In the T-tube, which has been extensively studied (27), a plasma is produced by a discharge across electrodes located in the arms of the T and is pushed down the tube by the magnetic field caused by the return from the electrodes, most commonly used as a backstrap across the top of the T. Some of the few available experimental data on efficiency were obtained with this device by measuring the momentum of the plasma with a plastic disk pendulum. The highest reported value was 7.4 per cent (28).

Moving Fields

Another type of device currently receiving attention in the laboratory is that employing a traveling wave tube to create a moving magnetic field for accelerating the plasma. This type of device has been constructed in order to eliminate eletcrodes, and relies on induced current loops in the plasma to insure interaction with the magnetic field. It is thus analogous to the electric induction motor, in which currents are induced in the closed loops of the armature and pushed by the magnetic field, which moves from pole to pole.

Traveling wave tubes have been used successfully to accelerate plasmas produced by r-f induction heating (24) and supplied by a conical shock injection system (29–30). The latter traveling wave tube was developed during the past year and uses a lumped parameter transmission line along which capacitors discharge in turn, successively energizing the coils of a helix. The result is a current front which travels down the line at a velocity dependent upon pre-assigned design parameters. Current loops induced in the gas by the current in the helix interact with the magnetic field and the result is a propulsive force. Streak photographs of the discharge of this tube with a hydrogen plasma have shown that the magnetic field does accelerate the plasma and that the field

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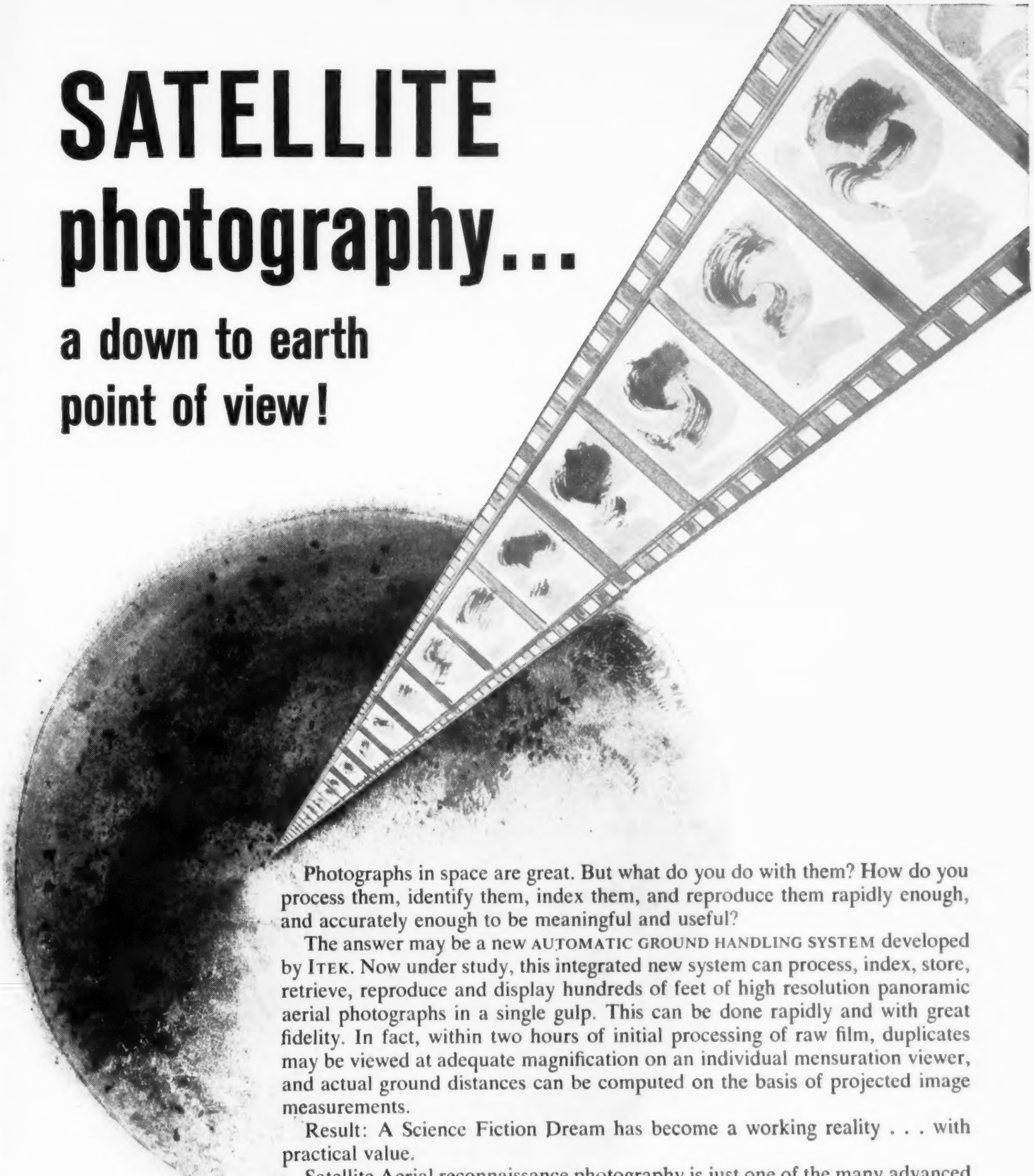

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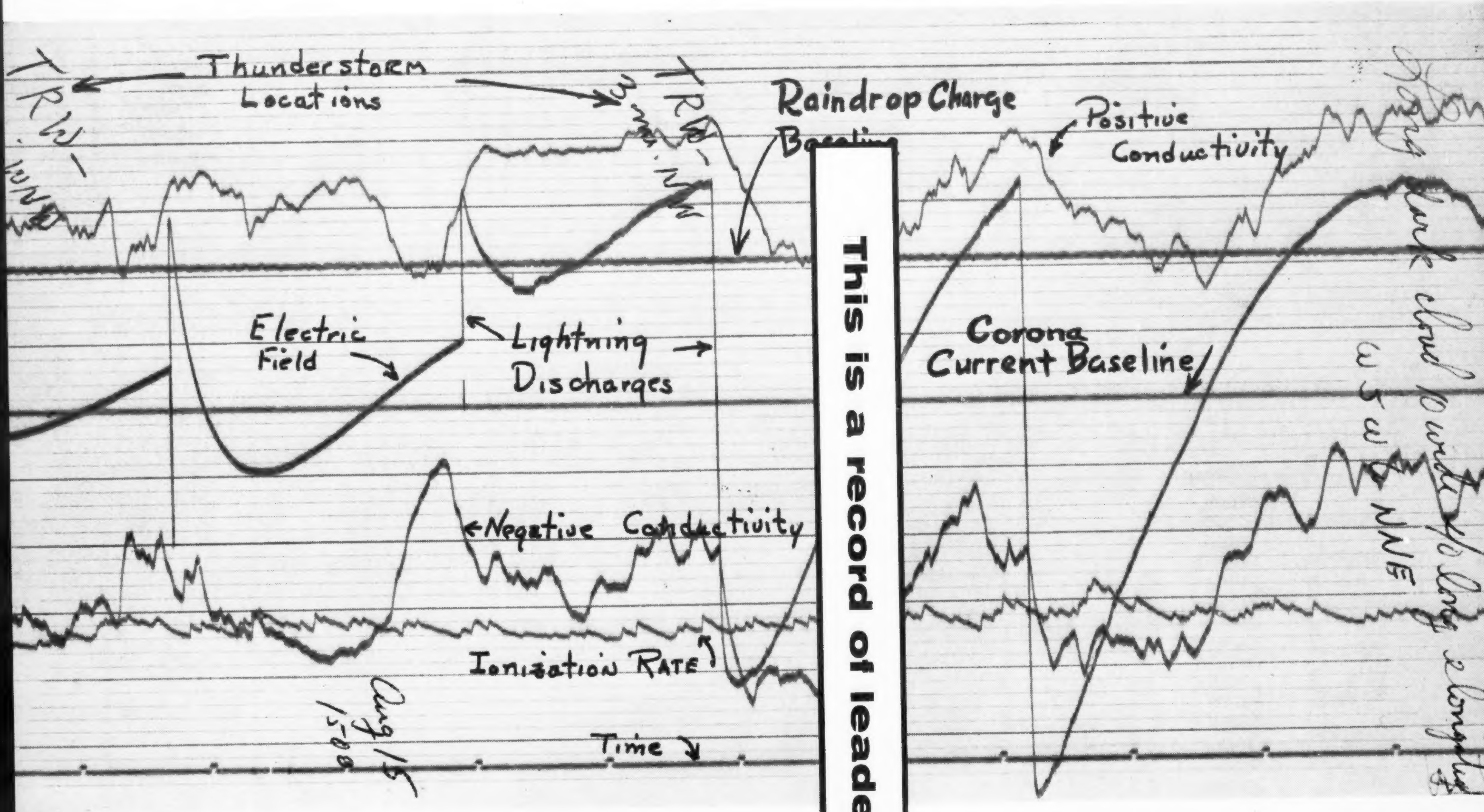

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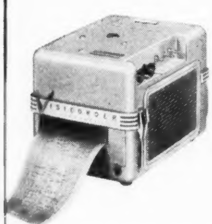
The Visicorder made this and many other records on t. Washburn without the use of power amplifiers. This ature, plus the extreme portability of the Visicorder, ade it the ideal oscillograph for use in these studies.

Byron Phillips, U. S. Weather Bureau Scientist, monitors thunderstorm data as it is recorded by the Honeywell Model 906 Visicorder.

hip n weather research



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OM HONEYWELL... A DIAMOND JUBILEE PARADE OF PRODUCTS

and plasma are locked together for distances up to 30 cm.

Principal efforts with plasma-propulsion devices in the past year have revolved around developing improved diagnostics to evaluate system performance. These include ballistic pendula, a piezoelectric pressure gauge of extremely short rise time, various types of gauges for determination of heat transfer rates to the wall, and spectographic techniques.

Among the critical problems to be faced in the development of the plasma engine are those of wall erosion and heat losses to the walls. Plasma propulsion can be expected to profit somewhat from increased size as development progresses. For given erosion rates, the larger devices will tend to be more reliable due to this smaller surface-to-volume ratio, and there appear to be no strong limitations to the size of the plasma engine. To counteract this source of energy loss, magnetic insulation in the form of an externally applied longitudinal magnetic field has been proposed. Magnetically insulated shock tubes have given evidence of successful magnetic channeling of a plasma (31,32), but little data exists on the effectiveness of such insulation on a propulsion type device.

It can be seen that plasma propulsion is still a field in which a large number of devices are under consideration and where research has not yet converged toward well-defined techniques. The principal need at present is for more data on the operation of the devices and the development of improved diagnostic techniques. Further work will also be required to develop devices capable of repetitive firing, since most existing apparatus are single-shot devices operating from a capacitor discharge. It should be emphasized that there is no difficulty in obtaining the high exhaust velocities corresponding to high specific impulses with present plasma propulsion devices. The most pressing problems are those of obtaining increased efficiency and reliability, and it is in these areas that significant advances must be made.

Acknowledgments

The section in this report dealing with electrothermal propulsion has been adapted from Ernst Stuhlinger's "Progress in Electrical Propulsion Systems," presented at the XIth International Astronautical Congress, held in Stockholm, Sweden, in August 1960. The section on electromagnetic propulsion was prepared by R. X. Meyer.

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Human Factors

(CONTINUED FROM PAGE 35)

flight. However, what has been utilized to a large degree up to the present time is the technical skill and knowledge which was available at the beginning of the U.S. space program. Basic information at hand is being consumed by present R&D programs at a tremendous rate, and it is not inconceivable that a plateau in technical development in this area could result if basic and applied research do not come into balance.

This might mean another period in which technical advances would have to await basic research data which would not immediately be available. It is thus time to review once again the problem of keeping development work and research abreast of each other, so as to insure that future program schedules can be met.

Progress in the life sciences has also been pointed up by increasing emphasis on this subject at technical meetings of various societies during the past year. There has scarcely been a meeting which has not included human factors sessions, and the ARS Committee in this area has frequently been called upon to suggest speakers and topics for such sessions. This type of lateral support has been found necessary despite increased emphasis on human factors at ARS meetings.

The 14th Annual ARS Meeting in Washington last November was highlighted by the presence and participation of a Soviet delegation which numbered among its members A. A. Blagonravov of the Soviet Academy of Sciences, a leading figure in the Russian biosciences program. This gave members of the U.S. human factors community a chance to meet with Russian scientists and discuss the Soviet program of biological experimentation which led to their recent suc-

cesses. While the Soviet delegation was unwilling (or unable) to discuss in detail future programs in this area, films shown at the meeting and informal talks indicated that the U.S. biosciences program would require additional emphasis if the gap in biological experience was to be closed within a reasonable period of time.

This year's ARS Semi-Annual Meeting featured two excellent sessions on human engineering and the allied engineering uses of human factors in the design and testing of systems, and sponsorship of at least two sessions on human factors is planned at each national ARS meeting as long as the quantity and quality of material available for presentation warrants it.

Specialist Meetings

Two other ARS-sponsored activities are worthy of mention. In May, the Committee sponsored a special meeting at Patrick AFB in cooperation with the local ARS Chapter and AF personnel at the base. This was a one-and-a-half day briefing on the Cape Canaveral complex and its operation, the Discoverer biological program, and the NASA biomedical effort in Project Mercury. Purpose of the meeting was to acquaint company representatives with the problems which were being encountered in such programs and to show them how their ideas and products were being utilized. Some 35 companies were represented at the meeting, and the general opinion of those who attended was that further meetings of this type should be held.

The second special meeting was the ARS Specialist Conference on "Anatomy of Manned Space Operations," held last month at Dayton. The program for this symposium was organized in response to a number of specific requests addressed to the Committee, and in the future similar conferences will be organized when attention is drawn to a specific area which requires general discussion of this kind.

Suggestions as to future briefings such as that held at the Cape in May or for Specialist Conferences should be addressed to the Committee.

The other major item of progress during the past year concerns the Committee itself, which has been reorganized, with a number of new members and consultants appointed. The reorganization was carried out in order to feed a blend of new and old members into the Committee, and also to broaden the membership so as to reflect the various human factors areas embraced by the Society's present activities. ♦♦

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People in the news

APPOINTMENTS

NASA has appointed **Robert G. Nunn Jr.** as special assistant to T. Keith Glennan to work on policy problems related to communications satellite systems. **Roy E. Godfrey** has been upped to deputy director of the Systems Analysis and Reliability Div. of the George C. Marshall Space Flight Center, and **Hermann H. Kurzweg** becomes assistant director for aerodynamics and flight mechanics in the NASA Office of Advanced Research Programs. **Martin J. Swetnick** has been made responsible for the agency's instrumentation of Lunar and Planetary Exploration Programs.

Walter T. Bonney, formerly director of NASA's Office of Public Information has been named to the same post for Aerospace Corporation, the AF's new scientific and technical planning and management organization for its missile-space programs.

Richard D. Linnell, vice-chairman of the ARS Hypersonics Committee and formerly staff scientist, Convair Scientific Research Laboratory, has been appointed Chance Vought Professor of Aeronautics, Engineering Dept., Southern Methodist Univ.

Austin Corbin Jr. has been appointed systems engineering manager of the Slam Project at Chance Vought Aircraft. He previously was with the ANP Department of General Electric.

Peter P. Wegener, formerly chief, Gasdynamics Research Section, Jet Propulsion Laboratory, has been appointed professor of mechanical engineering, Yale Univ.

J. Norman Rossen has been promoted from assistant director to director of the Solid Propellant Div., Atlantic Research Corp. **Egon A. DeZubay** has joined the company's technical staff as a fuels and combustion specialist.

John Harlan Kerr, secretary of Thompson Ramo Wooldridge Inc., has been named vice-president and general counsel. Also elected to vice presidencies are **George W. Fenimore,** general manager, International Div., and **Warren B. Hayes,** general manager, Electronic Components. **Victor P. Kovacik** will direct preliminary design activities of Tapco's New Devices Laboratories.

Raymond C. O'Rourke has been named to head the new Advanced Research Dept. set up by Edgerton, Germeshausen and Grier, Inc. **Clyde B. Dobbie, Donald F. Hansen,** and **Marion P. Shuler Jr.,** who have worked with O'Rourke for NRL during the past 10 years, have joined him.

At California Institute of Technology, **M. L. Williams Jr.** has been promoted from associate professor to professor of aeronautics and **E. E. Zukoski** from assistant professor to associate professor of jet propulsion.

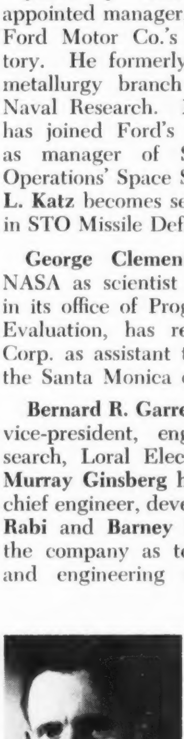
Col. Clair E. Ewing has been appointed deputy commander of the AF's Pacific Range Headquarters, Pt. Mugu, Calif.

David R. Heebner, manager of Hughes Aircraft's Undersea Warfare Dept., has taken a one-year leave of absence to serve on a panel of the National Research Council sponsored by the National Academy of Sciences.

Julius J. Harwood has been appointed manager, Metallurgy Dept., Ford Motor Co.'s Scientific Laboratory. He formerly was head of the metallurgy branch of the Office of Naval Research. **Herbert L. Karsch** has joined Ford's Aeronutronic Div. as manager of Space Technology Operations' Space Systems and **Elliott L. Katz** becomes senior staff specialist in STO Missile Defense Activity.

George Clement, on leave with NASA as scientist for vehicle design in its office of Program Planning and Evaluation, has rejoined The Rand Corp. as assistant to the president in the Santa Monica offices.

Bernard R. Garrett has been elected vice-president, engineering and research, Loral Electronics Corp., and **Murray Ginsberg** has been appointed chief engineer, development. **Isidor I. Rabi** and **Barney Maltz** have joined the company as technical consultant and engineering representative, respectively. Dr. Rabi has been chairman of the President's Science Advisory Committee. In 1944, he received the Nobel Prize in Physics.



Linnell

Haneman

Vincent S. Haneman Jr., former chief, Special Projects Div. of the Guidance and Control Directorate, AF Ballistic Missile Div., has resigned to open an astronautical and instrumentation engineering consulting office in Dallas Tex.

Wallace Kantor has joined the Astro Science Group, Space Physics Laboratory of Northrop Corp.'s Norair Div.

John N. Sherman has been named project superintendent of the new Space Propulsion Dept. of Hercules Powder Co.'s Bacchus Works, Utah. **Albert R. Ely** becomes assistant to the director of operations of the company's Explosive Dept., and will be succeeded as manager of the Kenvil, N.J., works by **Richard C. Tucker. Bevier H. Sleight, Jr.** replaces Tucker as manager of the company's Radford Arsenal, Va.

HONORS

Exceptional and Meritorius Civilian Service Awards have been presented by ABMA to **Arthur Rudolph** for his contributions while serving as project director for development of Redstone and Pershing. He currently is head of ABMA's new Research and Development Directorate. **Konrad K. Dannenberg** was recognized for meritorious service as project director for Jupiter.

Col. Thurston T. Paul has received the Air Force Commendation Medal for his meritorious service as chief of the Jupiter Project Office and as deputy commander of ABMA.

DEATHS

Hermann I. Schlesinger, emeritus professor of chemistry at the Univ. of Chicago and a pioneer in boron hydride research, died last month in Chicago at the age of 77. Dr. Schlesinger and an associate, Anton Burg, became interested in the boron compounds in 1930 and found that their production could be greatly increased by means of an electrical discharge. The technique opened a whole new field in chemistry and led to the later synthesis by Dr. Schlesinger of lithium aluminum hydride.

♦♦

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. . . a new structural system interlocking Min-K insulation and high-temperature reinforced plastic

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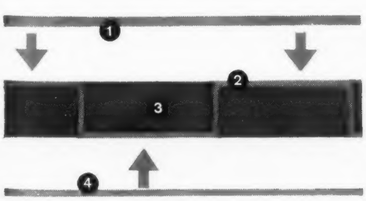
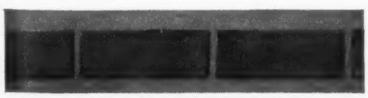
Like all J-M Aviation insulations, Min-Klad Interlok is factory-fabricated to your specifications into external skin panels, heat shields, cylindrical liners or component housings of any shape or size. Write today for technical specifications. Address Johns-Manville, Box 14, New York 16, New York. In Canada, Port Credit, Ontario.



1) Outer facing, 2) Interlocking web, 3) Core, any one of several Min-K formulations, and 4) Inner facing.



All the above components combine to provide a custom-made structural strong insulating system.

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Power Systems

(CONTINUED FROM PAGE 43)

point where operation at 0.8 to 0.9 volt at 100 amps/ft^2 is now possible for prolonged periods. Thermodynamic efficiencies (electrical output/free energy of combustion) for such cells are approximately 65 per cent at this current density. Continuous operation is limited at the present time by problems relating to the removal of water from the cells through the porous electrodes of the cells. Union Carbide has operated cells of this type for periods of up to 2 years without failure. These cells should be available for general use within the near future (perhaps 1 or 2 years) in the form of batteries with continuous ratings of several hundred watts.

Improved performance and hardware have been developed for the Bacon cell by the Patterson-Moos organization and for the ion-exchange membrane cell by GE. Both of these cells consume hydrogen and oxygen. The GE ion-exchange membrane cell lends itself particularly to small-scale applications, such as satellites; it does not have a fluid electrolyte but, rather, uses an ion-exchange membrane through which hydrogen ions migrate. The promise of the system may depend on the ability to construct relatively trouble-free operating systems of small size without complicated auxiliary equipment.

Cryogenic storage is particularly favorable due to its light weight, and the possibility of using the hydrogen liquid as a heat sink for control of the vehicle environment. Cryogenic storage of hydrogen and oxygen is currently practicable with losses of less than $^1/_2$ per cent per day. Calculation of chemical system weight should include such items as the water required for cooling. Also, the vehicle designer should take into account the over-all weight savings realized when using chemical fuels for such purposes as a heat sink, oxygen supply, etc. Particular emphasis has been placed on these systems in the past year, but major problems exist in system integration, due to variable cooling and power loads.

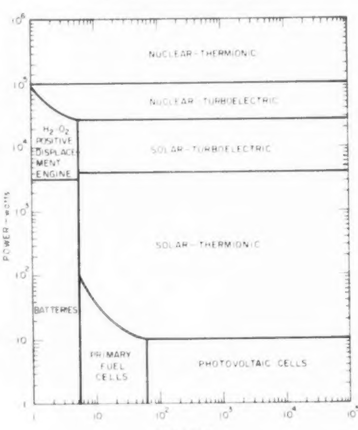
Electrochemical storage will continue to be used with photovoltaic power systems and for special loads where high-power, short-duration bursts are required. In the near future the nickel cadmium batteries appear most favorable where long cycle life is desired. Battery weight depends on the maximum allowable charging rate of about 10 hr. With current technology the effective specific weight of the nickel cadmium storage system would be approximately 700 lb/kw at a satellite altitude of 300 mi, decreasing to perhaps 100 lb/kw in a 24-hour orbit. In the future, with a 5-hr charging rate, battery specific weight may decrease to the range of 200 to 50 lb/kw. Improvements in storage battery performance reported during the past year include better sealing techniques, which can be relied upon to prevent loss of water, and improved separator materials. Beyond 1965, reversible fuel cells will probably be used with specific weights on the order of 20 lb/kw at 300 n. mi. Two hydrox cells currently in the experimental stage, the GE ion membrane and the EOS porous matrix, do not depend on gravity and use the same electrodes for electrolysis and power generation. As yet, storage efficiency is low.

Exotic Fuel Cells

Several regenerative fuel-cell systems may employ nuclear or solar energy to dissociate compounds which can then recombine in a fuel cell. Closed-cycle fuel-cell systems which appear promising include NOCl (photochemical) and LiH (thermal regeneration) types. A major breakthrough is required in achieving high system efficiency before this type of energy converter will be competitive with other thermal or direct conversion mechanisms. No spectacular gains have been reported in the past year.

Photovoltaic power systems are currently the only practical means of providing energy to space vehicles for long durations. In the past year, solar-cell efficiencies have been significantly raised; now 13-per cent cells can be obtained commercially in quantity, and solar-cell panels can be built to provide 11 per cent in space. This efficiency improvement has been largely due to the use of a new gridded solar-cell structure which spreads electrical contact over the cell surface.

1970 Space Power Systems of Minimum Weight



The continued use of photovoltaic cells at power levels less than 100 watts is virtually certain, and they will remain competitive up to levels of a few kilowatts. The weight of the solar-cell system will depend significantly on the integrated Van Allen flux encountered during system lifetime. Without Van Allen radiation protection, large flat solar-cell arrays can be built to weigh on the order of 0.5 lb/ft^2. With the supporting framework and other auxiliary equipment included, a solar-cell power system could run on the order of 800 lb/kw in a 300-mi orbit with present techniques, this decreasing to 350 lb/kw in a 300-mi orbit.

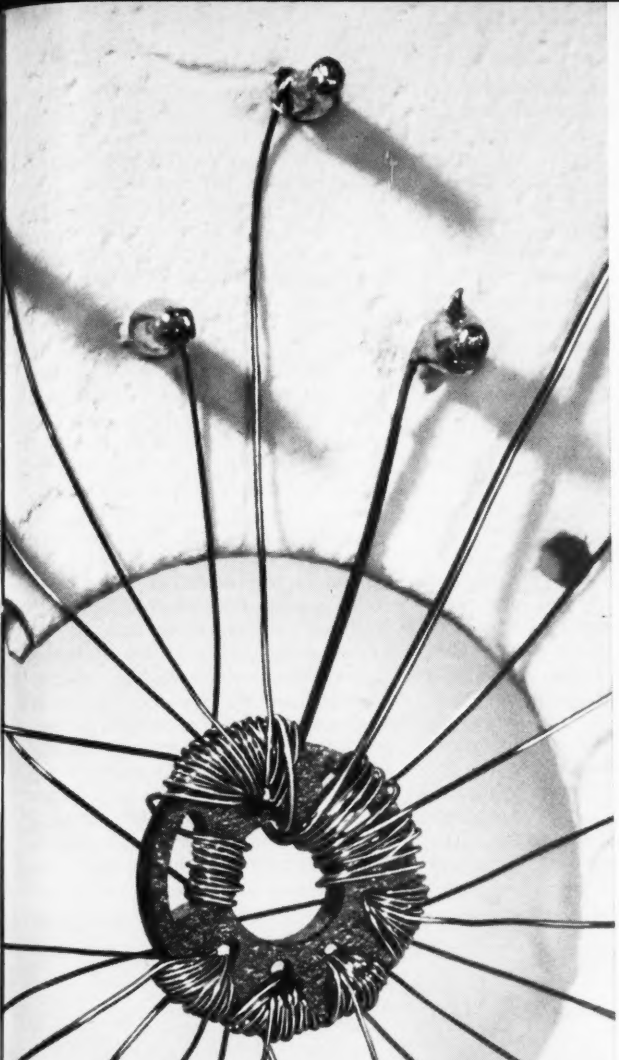
A system operating in the Van Allen region for more than a few months may require protective glass covers on the order of 50 mils in thickness and an equivalent amount of material on the rear of the solar panel, resulting in a weight of about 2 lb/ft^2 of solar array. System weight increases to the range of 1100 to 600 lb/kw depending on the orbit.

Future high-power solar cell systems probably will use concentrating devices to increase illumination on the solar-cell surface and decrease over-all system weight and cost. Simple flat-plate concentrators appear useful from the viewpoint of ease of fabrication and packagability. Weight and cost reductions on the order of 30 to 50 per cent appear possible within the next few years. By 1965 photovoltaic systems weighing on the order of 150–200 lb/kw are possible. The present cost of photovoltaic power systems is high, on the order of \$400–\$600/kw. Improved manufacturing techniques may halve this cost in the near future.

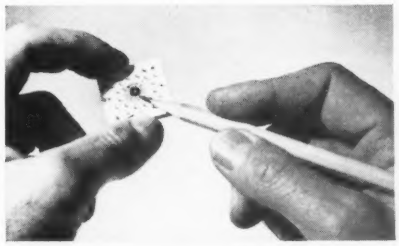
Now, as a result of the past two years' effort, solar cells are available in abundant quantities at reasonable cost and with a high degree of reliability. Two years ago only about 10 per cent of the cells produced were of military value; today, over 50 per cent of the production is of military value and, in general, of better quality. These figures are expected to improve in the future as a result of further research and development.

Silcon-solar-cell converters, their reliability and capabilities proved, are now almost commonplace for satellite use. They have been used successfully in Explorer VII, Pioneer V, Tiros, and several Sputniks. Due in part to the early pioneering of the Signal Corps, silicon solar cells are considered the most suitable power source for most of the satellites planned for the near future.

Several solar-thermal systems are



opportunities in
systems development



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being developed using paraboloid mirror concentrators which transfer solar energy to thermionic emitters, thermocouples, Rankine-cycle turbines, and the Stirling engine. Major system components will include the mirror, a cavity-absorber structure, storage (either thermal or electrochemical), converter, radiator, conversion and regulation circuits, and other auxiliary equipment. The design of the cavity-absorber structure will depend heavily on whether a static converter is used where the waste heat is conducted directly to the cavity exterior surface or a working fluid transfers heat from the absorber to the auxiliary radiator structure.

The required geometrical tolerance of the paraboloid mirror surface is a strong function of the cavity temperature. In the past year, lightweight concentrators using a double-skinned aluminum honeycomb structure weighing about 0.3 lb/ft^2 have been constructed which can provide approximately 70 per cent concentrator-absorber efficiency (including re-radiation losses) at temperatures of about 1300 F, this dropping to perhaps 30 per cent at 2000 F. Models up to 10 ft in diam which fold like a flower with 20 petals have been constructed for the Sunflower program (TRW). Temperatures of 1300 F are suitable for use with current models of the Stirling engine, Rankine-cycle mercury turbine, and thermocouple. At higher temperatures, on the order of 2000 F, mirrors with greater accuracy and light weight will be required. This development represents a major challenge in the competition of solar-thermal systems with other types. A promising technique for higher-accuracy mirrors involves the formation of a solid skin; a small model of this type made by Electro-Optical Systems is shown on page 43.

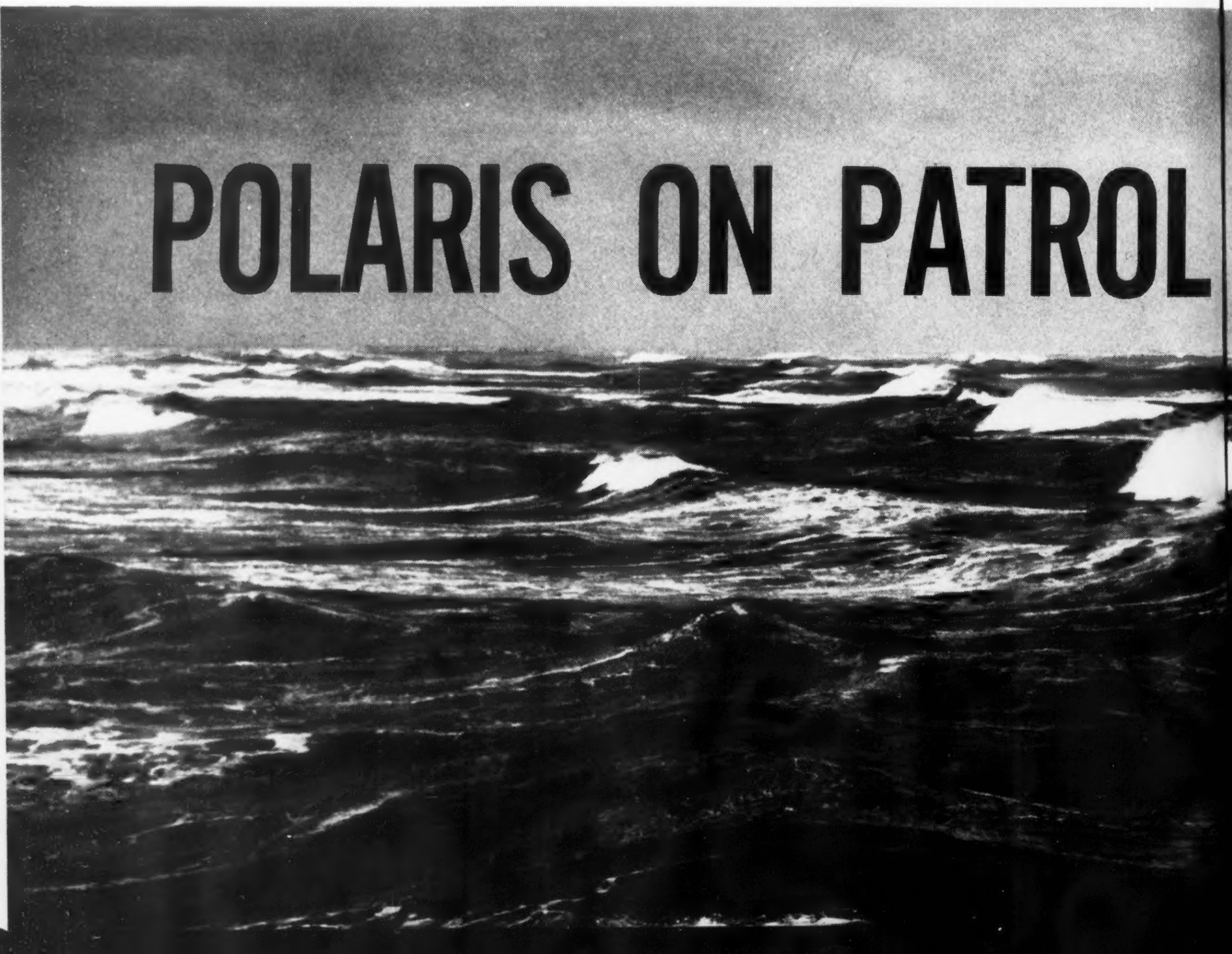
Dynamic Converters Now

At present, dynamic thermal converters—e.g., Rankine-cycle turbines and the Stirling engine—are advantageous at medium power levels due to their high efficiency and consequent size reduction of other system components, such as radiator, concentrator, etc. The chart on page 106 shows efficiency and temperature range of operation for the four heat engines of primary interest in the near future. The high temperature represents the upper limits of operation set by materials while the low temperature represents minimum system weight. The 1960 numbers are based on operational equipment as used in systems currently being developed. The 1970 numbers approximate the anticipated improvements in thermal converters predicted by industry. Static converter efficiencies are likely to surpass turbine efficiencies in the near future.

In the past year, significant improvement in the conversion efficiency of experimental static converters has been reported. Vacuum thermionic diodes operating at 5-per cent efficiency are about ready for the commercial market. Ten-per cent cesium diodes have passed from the experimental to prototype stage. Significant strides have also been made in developing adequate theoretical models which describe diode operation.

While thermoelectric-material "figures of merit" continue to rise in the laboratory, the best material continued to be lead telluride, which will provide 6–8 per cent efficiency in a typical system. The past year has witnessed the development of highly reliable, encapsulated thermocouple units in large quantity. These units have been successfully used in several radioisotope systems, such as Snap IA.

Progress has continued in dynamic converters. The Rankine-cycle mercury turbine used in Snap II has been tested for over 2000 hr. Applied re-



search work in the area of solar dynamic power covers both hardware experimental work and relatively more basic investigations. Hardware experimental work centers around the testing of a mercury Rankine unit in a weightless environment and the development and ground-performance testing of a power unit operating on the Stirling cycle. The more basic investigations are being conducted relative to achieving higher power levels with advanced fluids such as rubidium.

As an outgrowth of the Air Force Spud I program, efforts are under way to conduct a dynamic Rankine-cycle power-unit space experiment under AFBMD Project Piggyback. In this experiment the power unit, of the type developed under the Snap I and Spud I programs, will be comprised of a boiler, non-solar heat source, condenser-radiator, and a turbine-alternator-mercury pump assembly.

Early in August 1960, a power unit operating on a Stirling cycle underwent ground tests to verify the potential of the Stirling engine relative to the theoretically high performance of the engine. These tests will serve to provide initial indications of the endurance characteristics of the engine by operating the engine continuously for at least 500 hr. This engine is designed to be capable of producing 3 kw of electrical power for a year's duration.

Static heat engines may have the advantage of fewer moving parts or fluids in the over-all system and, therefore, higher inherent reliability. Specific weights of solar-power systems on the order of 50 to 100 lb/kw appear possible in the near future in the 1–30-kw range. When high-efficiency converters are developed, over-all system weight will be decreased by placing in thermal series the thermionic emitter (using a very high temperature heat source) and thermocouple.

Systems Being Built

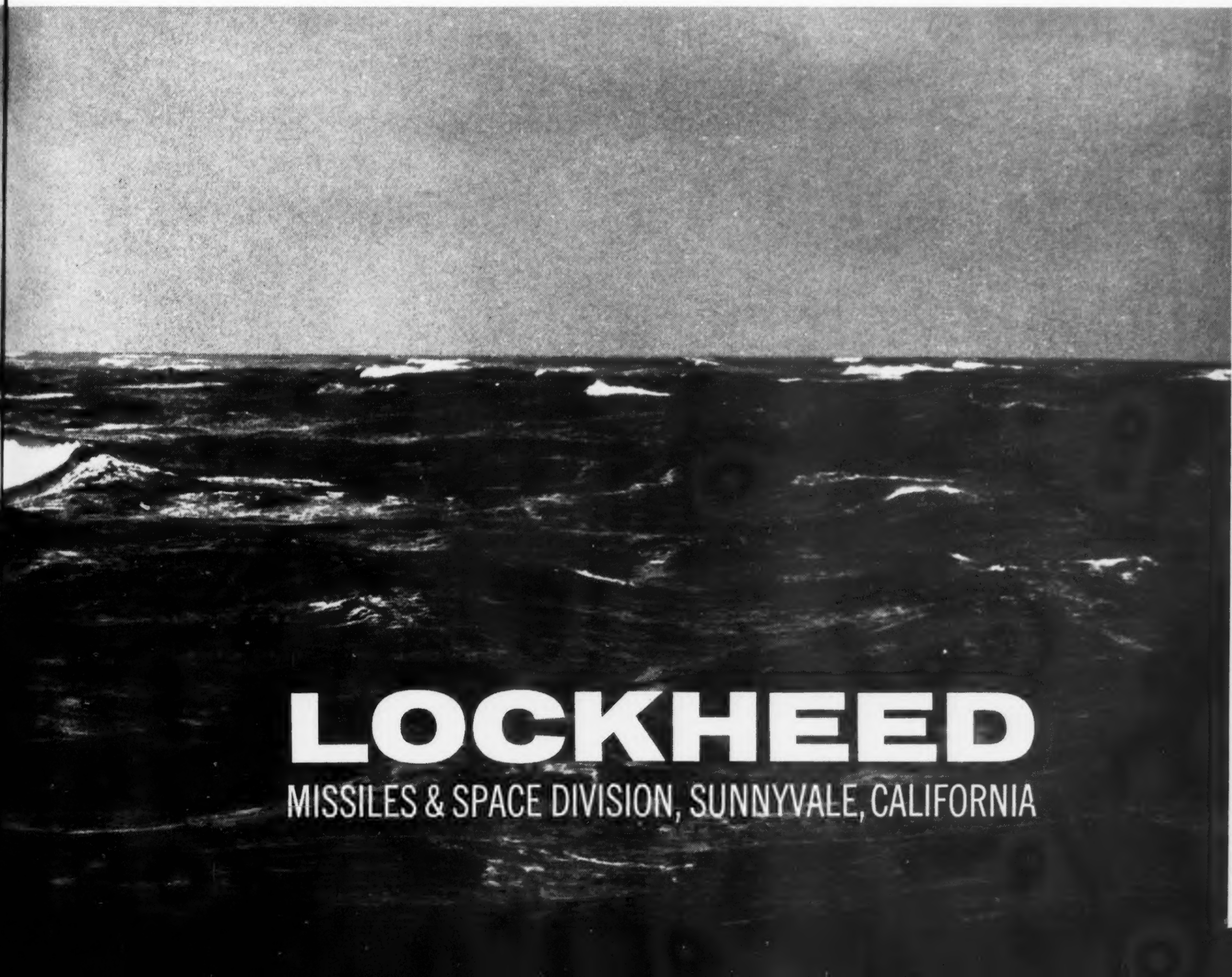
Systems currently being fabricated include several models of solar-thermionic and solar-thermocouple systems in the 50–100-watt range, with plans to expand these systems to the kilowatt range when feasibility is demonstrated. Many various photovoltaic systems, both oriented and non-oriented, in the 10–1500-watt range are being constructed. In addition, several solar-mechanical systems are being developed including:

1. The Sunflower program at TRW will result in a 3-kw system using a 32.5-ft-diam folding-petal mirror and a mercury Rankine cycle. The cavity operates at 1300 F, and lithium hydride is used for thermal storage. Total system weight is 864 lb and could weigh 465 lb if operated in the full sun. Over-all system efficiency is estimated to be approximately 10 per cent, and operational status may be achieved in 1962–63.

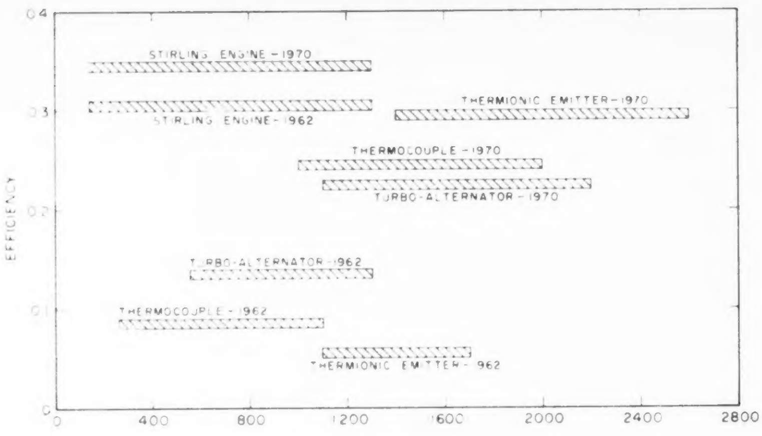
2. Sundstrand-Turbo, Inc. is currently developing a 15-kw power system using a folding-petal mirror with a 40.5-ft diameter and featuring a double-cavity type of boiler and flux trap. A rubidium Rankine cycle is used operating between 1750 and 675 F. Over-all electrical efficiency is predicted to be 22 per cent, over-all system weight 819 lb. Operational status is predicted for 1964–65.

3. The GM Allison Div. is developing a 3-kw solar-power system using the Stirling engine. Over-all system weight is predicted to be about 500 lb with an engine operating efficiency of 32 per cent. Operational status is perhaps 1962.

Nuclear-energy sources are logically divided into those based on nuclear reactors and those based on radioisotopes. It does not appear that radioisotope systems are competitive in terms of weight with solar-power sys-



Energy-Converter Efficiencies



tems where sunlight is plentiful. However, on special missions, where long periods of darkness are encountered (e.g., lunar surface), this picture may change. The complex considerations in selecting a radioisotope would include availability, cost, half-life, type of decay particle, and radiation hazards. It appears that radioisotope systems will be limited to power levels of a few kilowatts or less due to limitations of cost and availability.

For power levels above 20–30 kw and for durations of greater than a few days, it appears that nuclear reactor-turboelectric systems offer the lightest-weight systems for the near future. At high power levels (greater than 100 kw) the radiator dominates nuclear-system weight, and operating conditions should, in general, be selected to reduce radiator weight. Minimum radiator area occurs at a relatively fixed value of the ratio (approximately 0.75) of turbine outlet to inlet temperature. The radiator must be designed with either excess capacity, protective devices, or self-sealing mechanisms to compensate for destructive effects of meteorites. In the past year experiments have proved the feasibility of zero-g condensing radiators, but practically none of the practical construction problems are solved.

Reactor weight is a comparatively small part of the total powerplant weight at high power levels but becomes an appreciable percentage at power levels below 100 kw. Shield weight is roughly half system weight at lower power levels but drops to perhaps 20 per cent at high power levels.

The most prominent nuclear-power-system program for space projects is the Snap program sponsored by the AEC, with Atomics International the major contractor. By 1963 Snap 2, a 3-kw, nuclear-powered Rankine-mercury-cycle turbine system, will be operational. By 1965, the 30-kw Snap 8 will be operational. Studies are now being made for a 300-kw system to be available perhaps in 1968. Extensive design analysis and testing by the AEC and its contractors have demonstrated that nuclear-power systems can be launched, flown, and re-entered with negligible hazard to ground personnel.

A large amount of preliminary study has indicated the eventual weight superiority of nuclear-thermionic systems at high power levels and long durations. Practical systems are perhaps a decade away, with major problem areas remaining in emitter and reactor materials, i.e., emitter surfaces that will provide high power density (greater than about 20 w/in^2) with long life, and reactor materials that can reliably withstand operating temperatures of 2000–3000 K.

Acknowledgment

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Communications

(CONTINUED FROM PAGE 31)

the desired distances (1–3). Further, this must be accomplished without taking up so much of the payload for transmitter and power that no room is left for other electronic and optical equipment required to generate data which is to be transmitted via the radio-frequency link. This can further be reduced to a relationship between the amount of energy required for total bandwidth transmission or effective transmitted energy per bit or piece of information. Primary attention is focused on the mode of modulation used for transmitting the energy from the space vehicle, with secondary con-

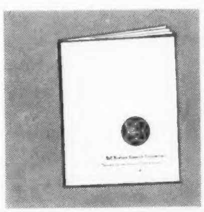
sideration for the generation of power to supply the modulator, the data generating devices, and the transmission oscillator of the system.

The techniques will of course vary, depending upon the specific application (4,5). What may be an extremely advantageous approach for one type of vehicle, such as Tiros, may be totally inappropriate for a deep-space probe. On the other hand, the type of information Tiros is transmitting is not necessarily of the same type as that required for an active communications satellite. In cases where it is possible to do some data processing within the satellite itself, the rate of transmission may be considerably lower than that in a satellite which does not possess the capability of data processing.

Consideration must also be given to the other end of the system, the ground receiving stations. With low-altitude satellites, such as Tiros, the relative speed at which the satellite passes a specific earth station is high, and the number of stations required on earth to collect the data could be considered large. Also, because of the close proximity of the satellite, the effective beamwidth of the antenna must be reasonable to allow acquisition and tracking. Conversely a deep-space probe or moon satellite is sufficiently far from the ground station to afford good coverage by a relatively small number of ground stations, perhaps three. The effective area covered by the ground antenna at moon distances and beyond is considerably larger than that of its low-altitude cousins. The size of these antennas can be extremely large since the differential earth-vehicle speed is slow for the deep-space satellites.

In examining the problem, the parameters which remain in effect are transmitter power, transmitter efficiency, and antenna system gain. Increasing transmitter power requires an increase in the source of energy and the size of components, and presents a complex temperature control problem. Increasing antenna gain means utilizing extremely efficient attitude control of the vehicle if gain is to be obtained from the transmitting antenna, or utilization of extremely large dishes, such as at Jodrell Bank (1,24). The remaining parameter which may effectively be utilized is transmitter efficiency (1).

In attempting to reconcile the differences, one must also take into account the importance of frequency. There is a definite relationship between frequency and the weight of a system. Essentially, antenna gain is proportional to the square of the diameter in wave lengths, and the



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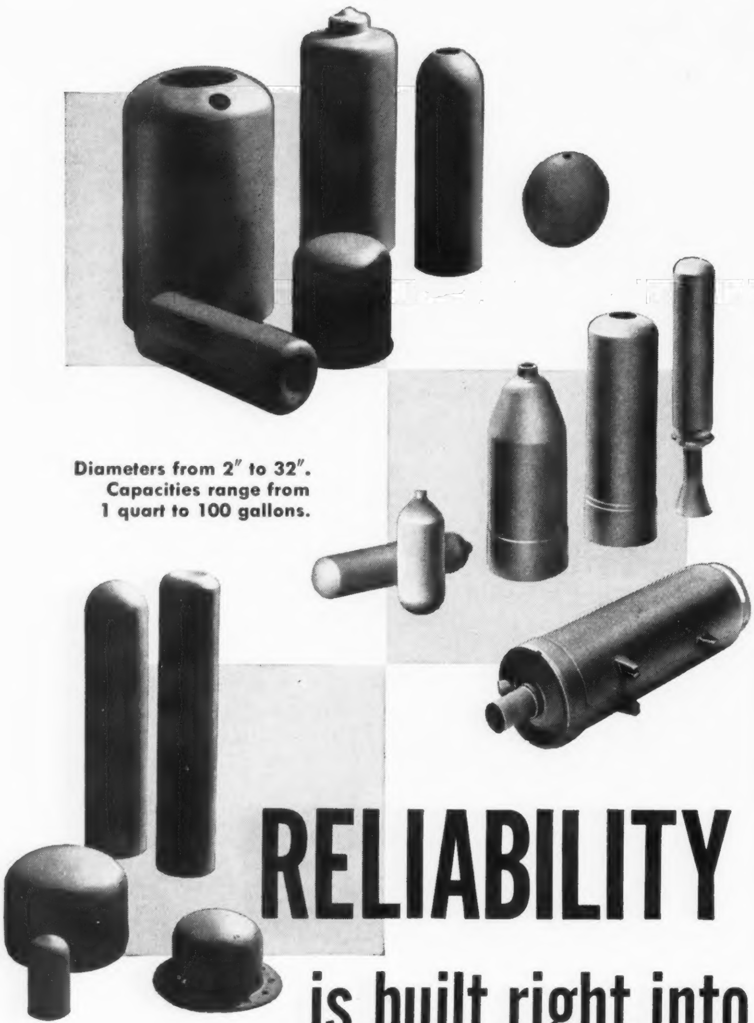

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weight of an antenna is proportional to its area. The weight of the power supply and the heat sink increases the frequency, since the efficiency of available transmitters decreases with increasing frequency. Therefore, the choice of an optimum frequency for transmission becomes an important factor.

In returning to the ground receiving station and its associated problems, the signal-to-noise ratio of the receiver becomes important (5,9), and the most important factor, even when utilizing parametric amplifiers and other such devices, is the bandwidth requirement of the receiver and, therefore, the bandwidth of the transmitted data. The other effect of received signal-to-noise ratio is the noise generated by stellar bodies (6), which relates again to bandwidth and look angle. In most space-probe and far-satellite problems, data bandwidths of approximately 10 cycles have been utilized.

As an illustration of what has been achieved, JPL's Microlock Receiver, utilizing a 250-ft ground antenna, can receive a usable signal of 10-cycle bandwidth with an effective radiated power of 100 watts from a vehicle in orbit about Venus, which is approximately 55 million mi from earth. The transmitter would weigh about 15 lb. On the other hand, the same system received by a 60-ft dish would require an effective radiated power of 1000 watts. Utilization of a parametric or maser amplifier (23) on the ground will reduce the power to 200 watts or the bandwidth to $^1/_2$ cps.

Transmitter Modulation

The problem reduces itself almost to a case of accepting for use with deep-space probes available ground antennas, and then concentrating on the modulation scheme for the transmitter which will yield the most efficient transmission for the type of information generated (1,5). Transmission efficiency has been fairly well established by Hartley and Shannon (27), who set up the ideal theoretical condition for the maximum amount of information which may be transmitted through a channel of given bandwidth with a given signal-to-noise ratio.

The first space-communication system used was the FM/PM analog telemetry system, developed by JPL and named Microlock, which has become the standard by which all systems are measured. Utilizing a phase-lock receiver, with a sensitivity of −50 dbm and a 10-cycle locked loop bandwidth, it permits transmission of six subcarriers with a theoretical modulation

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bandwidth of 0.8 cps with a realizable information bandwidth of only $^1/_{100}$ of a cycle over long distances. This system was able to transmit information successfully at lunar distances utilizing transmitter power outputs of approximately 100 mw. The combined total information rate for the system is about the equivalent of 0.5 bits per second. The system certainly was an advance over the type of system generally available at the time.

Microlock, a frequency multiplex system, was followed by orthogonal systems, such as Telebit and Digilock, which strive to approach the theoretical limits defined by Shannon, and are vastly more efficient than Microlock. STL, in developing a system for a deep-space probe, devised a digital telemetering system called Telebit (1,21). The system, utilizing 100 mw of power at lunar distances, will permit transmission of eight bits of information per second, or on command, at greater or lesser distances, will change power and transmit either 1 bit or 64 bits per second (1). The use of airborne analog-to-digital converters allows the information to be quantized and digitized so that once a message is received it will not be degraded by retransmission to a central station. The system provides, in addition, a transistor memory for storing the output of the experiments so that intermittent data transmission is possible.

Telebit is a digital system providing for transmission of information from space probes to ground and presentation of the information in processed form. The payload portion of the system accepts information from both analog and digital experiments and processes this information until it is in a suitable form for transmission. It commutates several types of pulses containing information to produce a time-multiplexed train of pulses containing information about a variety of experiments. The system collects information during the transmitter OFF period and then transmits it during brief ON periods.

Telebit transmission is made up of words in frames, a word being composed of 10 information pulses. The number of words which comprise a frame may be determined by the number of experiments required for a particular space mission. The number utilized so far has been 10 information words. Synchronizing signals are also inserted to ease the decommutation, or separation, problem on the ground. Two synchronizing pulses, always having the same form, are added to each word, and one synchronizing word is added to the set of each frame. Thus an entire word consists of 12 pulses, and an entire frame of 11 words. Pulse rate may be varied to 1, 8, or 64 pulses per second. Utilizing these rates, it takes approximately 132, 17, or 2 sec to transmit 1 frame. In addition, a device for subdividing a particular word has been utilized for slowly varying functions. This is normally referred to as subcommutation.

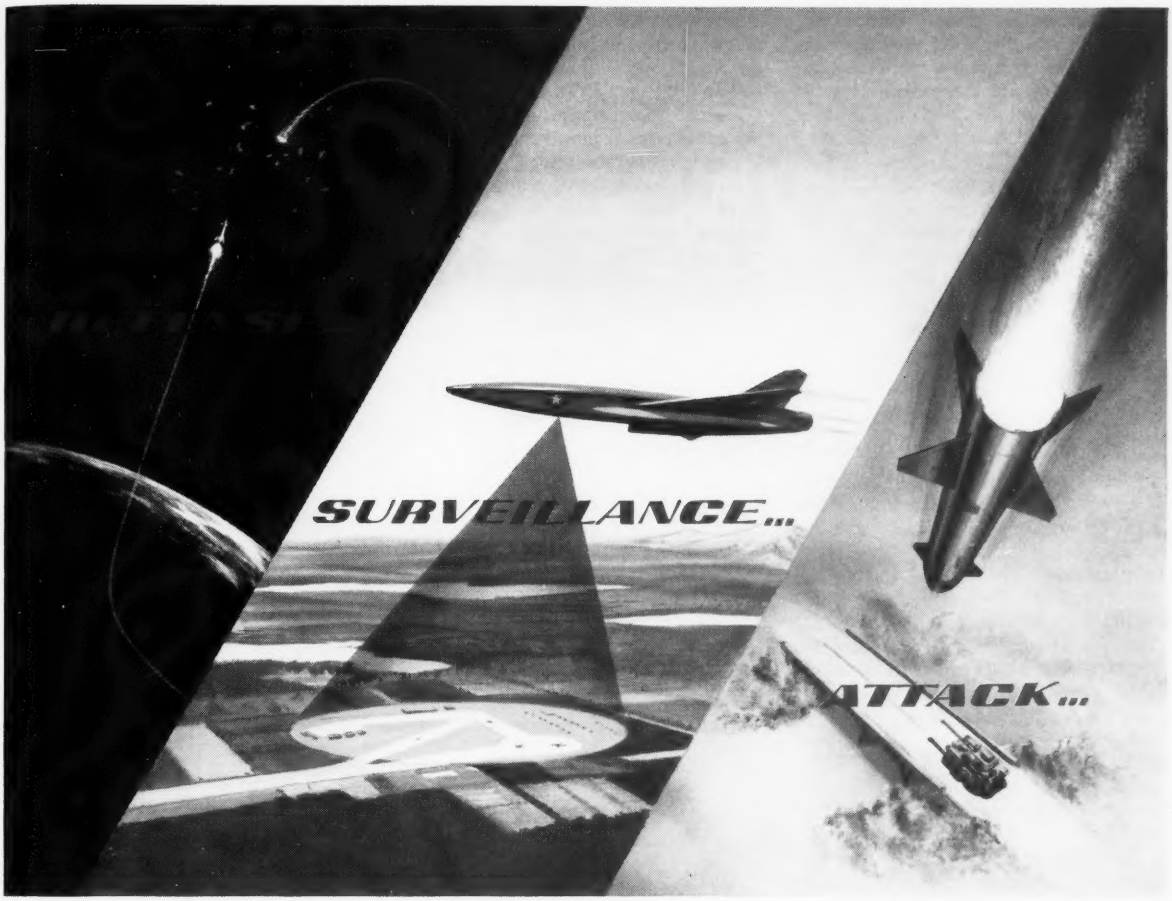
The transmission technique utilized for conveying information to the ground is bi-phase modulation of a subcarrier, which in turn phase-modulates an RF carrier. This technique has the advantage of providing a continuous carrier for acquisition and tracking from the ground. Unambiguous resolution of the pulse data is obtained through use of an adjacent pulse comparison bi-phase demodulator without a ground coherent oscillator. A disadvantage of the technique is approximately 6-db loss in signal-to-noise ratio because of limited subcarrier modulation power.

Designed Information Rate

In the system, efficiency of the transmitter may be controlled by decreasing the rate at which information is sent. Therefore, the system when utilized for a deep-space probe would transmit at a much slower rate than that used for a near-space experiment. An example is a typical mission to the moon, where it would be possible to transmit information at an approximate rate of 10^4 bits per second utilizing a 10-lb transmitter-antenna combination. The same 10-lb system, with an optimum antenna-transmitter, would be capable of transmitting only one bit per second from a space vehicle in the area of Venus or Mars. However, an increase in weight allocation would of course allow an increased information rate for the system.

Almost parallel with STL's development of Telebit, successfully demonstrated on Pioneer V, came the development by JPL, through a contract with Space Electronics Corp., of another digital deep-space transmission system called Digilock. An advanced pulse-code telemetry system, it was designed for ultra-long-range use. Digilock and Telebit are similar in many respects, but not identical.

Digilock samples an input data source, quantizes the data sample, transmits a coded representation of this sample, receives and decodes the data, and either stores or displays the information. It utilizes a coherent matched-filter detector. The power efficiency in Digilock is a factor of 20 better than that of conventional systems (21). It features variable data



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rate capability while maintaining power efficiency, and its accuracy can be varied by changing the information word length. Its mechanism is simple and its volume and weight are small. Four data rates may be utilized to accommodate 30 input signals. The preliminary system will have a power output of approximately 250 mw, and it will use an encoder weighing $1^1/_2$ lb and measuring 45 cu in.

Digilock will be used in the upcoming Armed Forces Special Weapons Center series of ultra-high-altitude tests, utilizing Journeyman B ultrahigh sounding rockets.

Tiros Observations

Tiros, the first operational weather satellite system, permitted observation of cloud-cover patterns over the entire earth by utilizing the medium of television and transmission techniques from an orbiting satellite. During its operational life of three months, some 23,000 photos were taken and transmitted back to earth. These transmissions utilized a bandwidth of over 100 kc, more than an order of magnitude greater than that utilized by any other previous satellite. Measurements from Tiros confirmed the free-space propagation calculations, and no unusual effects due to the bandwidth were noted.

The complex Tiros system was composed of TV, storage, transmission, and command and control subsystems (22). The TV subsystem utilized two cameras, one wide-angle and one narrow-angle. A set of two 10.5-lb tape recorders was incorporated into the storage system to allow continuous gathering of data. The stored data was transmitted to the ground during selected time periods, on command. The readout time was 2 sec per 500-line TV frame; the transmission bandwidth was 62.5 kc.

Activity in the field of communications connected with missile and aircraft tests continues to work toward improving the state of the art. To this degree, PCM has taken large strides over the past year (13,14,25,26). Minuteman, now in development, will utilize a PCM system as its major telemetering device. Not to be forgotten is the FM/FM system which will handle high-frequency data and will act as a backup.

This significant advance had uncovered several problems in PCM development. The Minuteman system is a low-level system designed to operate with inputs in the low millivolt region. Some difficulty was encountered in handling millivolt signals, and this caused a slight delay in the program. However, Minuteman, after its first series of flights utilizing FM/FM equipment, will be the first ballistic missile to fly a full PCM telemetry system.

The advent of PCM in missile work gives rise to an opportunity to measure some critical parameters to a high degree of accuracy which have never been measured previously. Prior to PCM telemetry, a problem existed in making measurements accurate to 0.1 per cent. Measurement of inertial-guidance parameters is a typical problem. A highly accurate instrumentation system was developed to operate under closed-loop conditions as a guidance system, which creates a requirement to develop a system of higher accuracy to monitor guidance-system performance.

In the past, successful measurements of inertial-guidance equipment have been made by adapting signals from the digital computer which forms a portion of the system. Adaptation of the signals calls for sampling, pulse stretching, storage, and then transmission—a technique which, although useful, was not considered adequate, since it did not allow accurate measurement of a number of parameters within the guidance system not in digital form. The PCM system will allow these functions to be monitored with extreme accuracy.

There are still several areas which require investigation before PCM will come into universal use, but evaluation of such systems will certainly take place within the next year.

In all probability, future telemetry systems will be hybrids, with some measurements—those requiring high accuracy and low frequency response—utilizing PCM techniques, while others rely on FM/FM for a lower order of accuracy but greater capability for transmitting information containing high-frequency components. In between these two areas will be the pulse systems, such as PAM, PDM, or PTM, which will not yield the accuracy of the PCM system, nor have the frequency capability of the FM/FM system, but will, within a restricted bandwidth, handle average measurements which may be sampled at a fairly low rate and do not require great accuracy.

Automation Advances

Data acquisition, data reduction, and instrumentation checkout systems have taken a large step forward through the utilization of automatic techniques. In many cases patch panels have disappeared and have been replaced by programming boards like those used in computers and switch panels, which allow a high degree of flexibility in setting up these complex systems. Ground station checkout is now often accomplished through automatic equipment which supplies calibrated signals as the input for the system. The systems are then programmed to perform as they would for received data, with their outputs automatically measured and printed on a digital printer. This technique normally can be incorporated with the standard test equipment designed into the system for maintaining and troubleshooting the system. Utilization of these automatic checkout techniques, such as those adopted in the Minuteman FM/FM ground station (15), increase the cost of the ground station by a nominal amount but pay for themselves through the reassurance they give the operators and data analysis people.

The time saved by utilization of automatic checkout allows more data to be run through the system per day than could previously have been handled with manual checkout procedures. This technique, using end-to-end calibration of the system, allows the system to be calibrated in a relatively short period of time prior to and immediately after each data run. The printed calibration may be attached to the data record, thereby increasing data reliabilty.

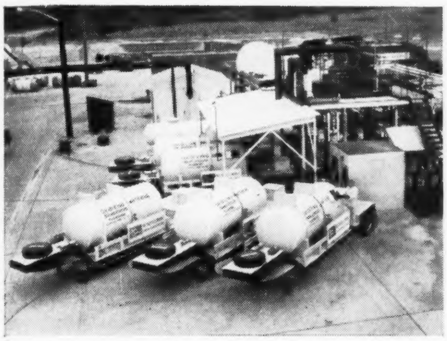
The techniques have been extended past the ground station to incorporate

Blue Scout Jr. Stage Separation

Separation of second and third stages of four-stage, solid-propellant AF Blue Scout Junior is shown in this artist's conception. Heat shields are seen falling clear of final stage, exposing the payload antenna. Successful test launches of both the 72-ft NASA Scout vehicle and the 40-ft AF Blue Scout Junior version of the vehicle were carried out in recent weeks.

FORECAST

Major space age role for fluorine rocket fuel oxidizers



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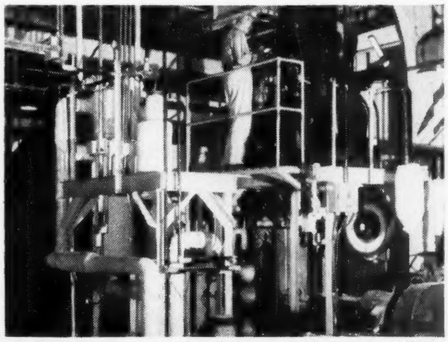

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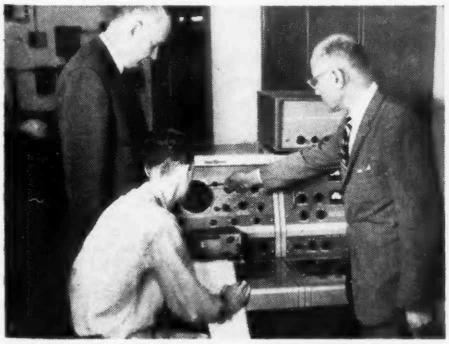

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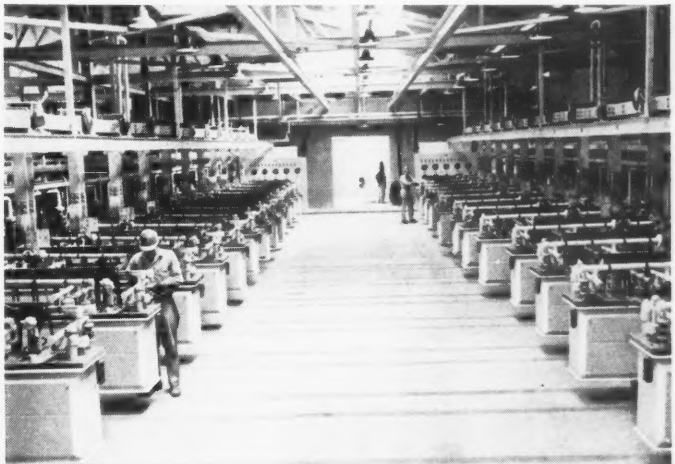

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airborne telemetering equipment, so that automatic checkout of airborne equipment may be accomplished through the ground equipment. Simulated signals originating in the ground station are sent to the airborne system. They respond, and transmit the encoded signals back to the ground station, which then decodes the signals, compares them with the original inputs and automatically prints out any deviations noted. Inclusion of a servo control will allow for automatic compensation of the signals or automatic corrections within the airborne system.

The state of the art now permits automatic calibration and checkout of an entire instrumentation system from a ground station which then can encode the answers and feed them to a central computer. ABMA has plans for automatically checking out all systems within its future missile systems through a master computer.

Without further extension of the state of the art, communications equipment will see more automation within the next year. In fact, automatic troubleshooting techniques will be incorporated into space probes and missiles. This will eliminate the necessity for lengthy data analysis to determine what problems may have occurred in a far-off satellite, which, hopefully, will transmit data for several months after a failure has occurred. Automatic troubleshooting and maintenance capability can be built into the instrumentation system so that, when a specific component or channel failure occurs, enough intelligence will exist within the system to determine the failure and switch in redundant equipment, thereby effecting its own repair. The limiting factor for utilization of such equipment in the past has basically been the size of the payload. The question has usually centered on the problem of determining whether or not another measurement should be included or a redundant self-troubleshooting system should be installed to safeguard a specific measurement. However, with larger payloads will come the capability for carrying sufficient weight to incorporate a self-repairing telemetering system within space probes and satellites.

The increase in size and weight capability of satellites and space vehicles such as Saturn and Dynasoar has posed some new problems for the telemetering fraternity. The number of measurements required on the Saturn booster is so tremendous that the use of former telemetry techniques would require an extraordinary number of transmitters to carry the data. Therefore, a complex time-multiplex

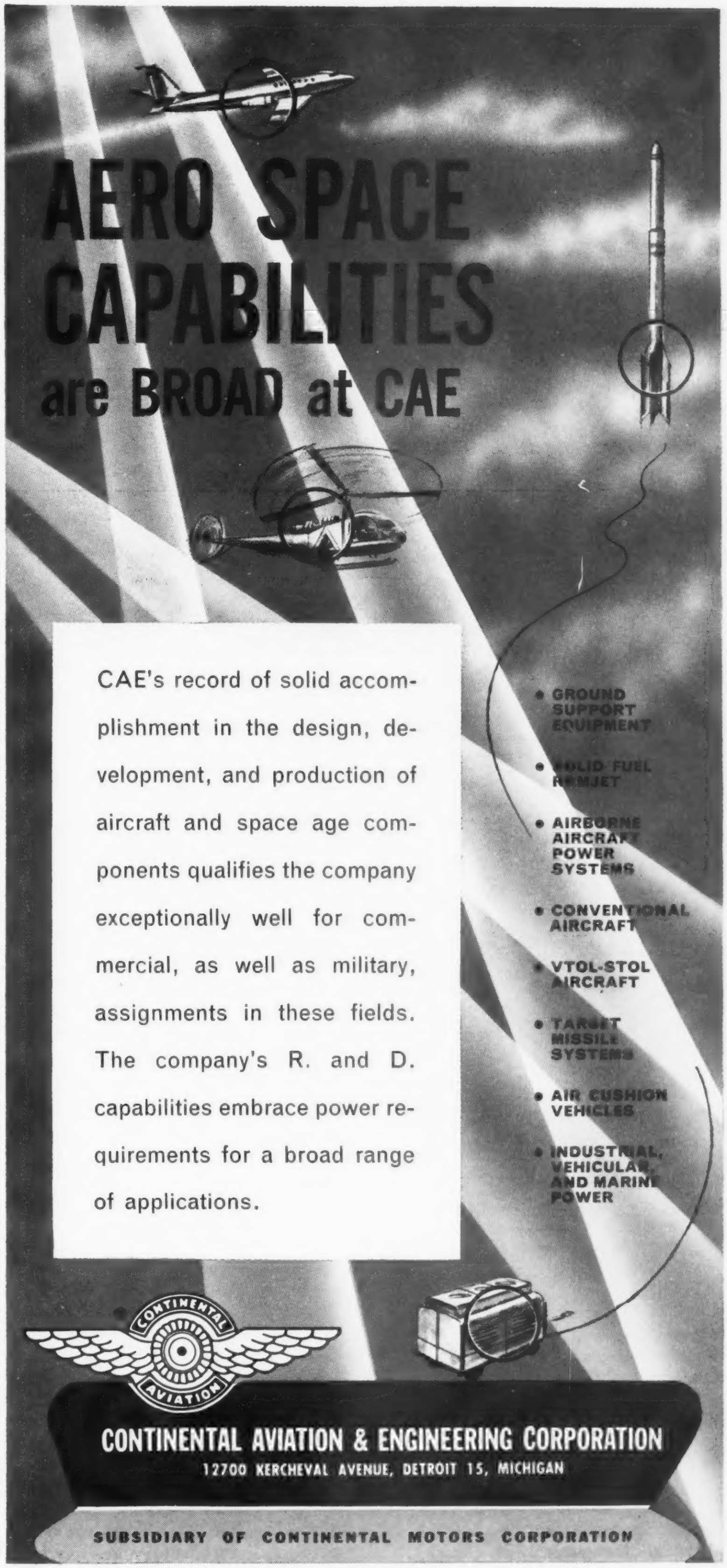
system utilizing sub- and sub-sub-commutated channels will be utilized to measure booster parameters. Measurements of the chamber pressure, temperature, and other critical parameters of each of the eight Saturn engines are necessary to evaluate its performance. This system is now operating in the breadboard stage at Huntsville and will be built by an outside contractor some time this year.

Problems encountered in such vehicles as Dynasoar require a large number of highly accurate high-frequency measurements. The probability that these measurements can be made successfully within the existing standards is very small. Therefore, an extension of the state of the art will be required for adaptation of some of the nonstandard techniques (12,19), such as frequency translation (10,17), PA/CM, or hybrid systems seems likely.

PA/CM Announced

A new system announced during the year, PA/CM, developed by Aeronutronic under government contract and now under theoretical evaluation, incorporates both pulse-code and pulse-amplitude modulation techniques. The flexibility of the system allows a division between measurements on an individual system basis. Over-all system capability may be divided up in desired proportions between pulse-code and pulse-amplitude. The system, a unique adaptation of both techniques, will be studied for the next six months to determine its practicability and advantages and disadvantages.

Echo, the first major passive communications satellite (7), was used for experiments on long-range transmission by reflection. This satellite, which orbited the earth for some weeks, could be tracked optically, electronically by reflection of radio signals, or by use of two radio beacons aboard the 100-ft balloon. The beacons represent an advance in the state of the art. Each is approximately the size and shape of an ordinary dinner dish and is equipped with a tiny radio transmitter no larger than a cigarette lighter. The two beacons, the only active electronic devices on the satellite, were installed on opposite sides of the balloon and broadcast a continuing tone as Echo moved in its orbit. The signals were used to provide a constant radio fix from the directional ground antennas used experimentally to communicate from point to point by reflecting messages from the balloon's aluminized surface. Each beacon is built about a $^1/_2$-oz transistorized transmitter, which along



with a miniature storage battery, is embedded in molded plastic to form a complete assembly. An 11-oz disk, 10 in. across and $^3/_8$ in. thick, designed to fit snugly against the huge balloon, constituted the entire assembly. On its upper surface, each disk carried an array of 70 solar cells to produce power from sunlight and a circular groove holding a slender antenna. The device was developed by RCA's Astro-Electronics Products Div.

The transmitters were activated when the balloon was inflated to its full diameter. At the same time, the antennas for each of the units sprang erect from their grooves and were ready for operation. The combination of solar cells and rechargeable storage batteries which operated the beacon provided power for Echo both in sunlight and shadow. Sufficient solar cells were designed into each of the arrays so that one could generate enough power to operate both beacons and recharge both batteries. The two beacons were linked together by thin printed wiring that circled the inflated balloon so that both transmitters were powered from a solar cell array when only one of them faces the sun. The transmitters radiated over 5 mw of power at frequencies of 107.94 and 107.97 mc.

The future still contains many problems. Exploration of higher frequencies (11) for transmission from Dynasoar and other vehicles, pre-detection recording of telemetry signals (16), advanced development of orthogonal systems, new FM/FM techniques (18), development of low-level electronic commutators, increased reliability (20), and others will maintain the requirement for the continued expansion of the state of the art in the years to come.

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Hypersonics

(CONTINUED FROM PAGE 36)

provided a much firmer understanding of Newtonian theory. Problems of unsteady motion were studied by using the explosion theory of Sedov (18), by applying the strip-flow assumption (19), and by a linear perturbation method (20). Similitude for slender bodies with blunt noses in real-gas flow was also discussed (21).

Inviscid flow of a nonequilibrium gas was considered in several papers. The flow behind a shock wave (22), around a sharp corner (23), along a wavy wall (24), and around a blunt body (25) were studied. Studies of the ionized wakes of bodies moving at hypersonic speeds were published (26, 27). Further study of the use of continuum equations for low-density gas conditions also appeared (28). A better understanding of the effects of rarefied gas conditions is slowly developing.

Viscous hypersonic flow received the most attention during 1960. Viscous hypersonic similitude (29) was discussed in an extension of the discussion appearing in the one book (30) on hypersonics published to date. Viscous similitude in a dissociating gas was also discussed (31). Another theory for the laminar boundary layer near the stagnation point appeared (32). The effect of vorticity and surface-temperature jump (33), and of injection of a combustible gas (34), was considered further in other papers. An approximation for the maximum heat transfer due to a turbulent boundary layer on a spherical nose was presented (35).

Data Presented

Experimental data was presented by several groups. The cases considered included transition on a shock-tube wall (36); a turbulent boundary layer on a wind-tunnel wall (37); laminar, transition, and turbulent boundary layer on a shrouded blunt-nose model (38); flow around afterbodies, using a shrouded model (39); boundary-layer transition on blunt bodies with highly cooled boundary layers (40); instabilities in the flow about bodies with surface cavities (41); and moderately low density viscous axial flow over a cone (42). The experimental facilities developed during the last few years are now providing experimental data needed not only to verify existing theories but also to provide a basis for models for further theoretical analysis.

Studies of ablation require consideration of viscous flow and its interaction with the melting or subliming surface as well. A survey article on recent advances in ablation appeared (43) in September 1959. Ablation of glassy materials was treated further (44), and theory and experiment were shown to be in good agreement (45). Ablation with sublimination was treated theoretically (46, 47) and experimentally (48). Tests of ablation of reinforced plastics were reported (49). An approximate theory for heat transfer to a vaporizing and ablating surface was based on previous results of boundary-layer-injection analysis (50). Publications on the application of ablation theory and experiment included one on the stable shape (51) of a slender ablating graphite body, one on the thickness of an ablating heat shield (52), and one on a comparison of heat-protection methods (53).

One of the most important areas in hypersonic viscous flow theory is that involving low-density gases and viscous interactions. The discussion of the proper equations to be used con-

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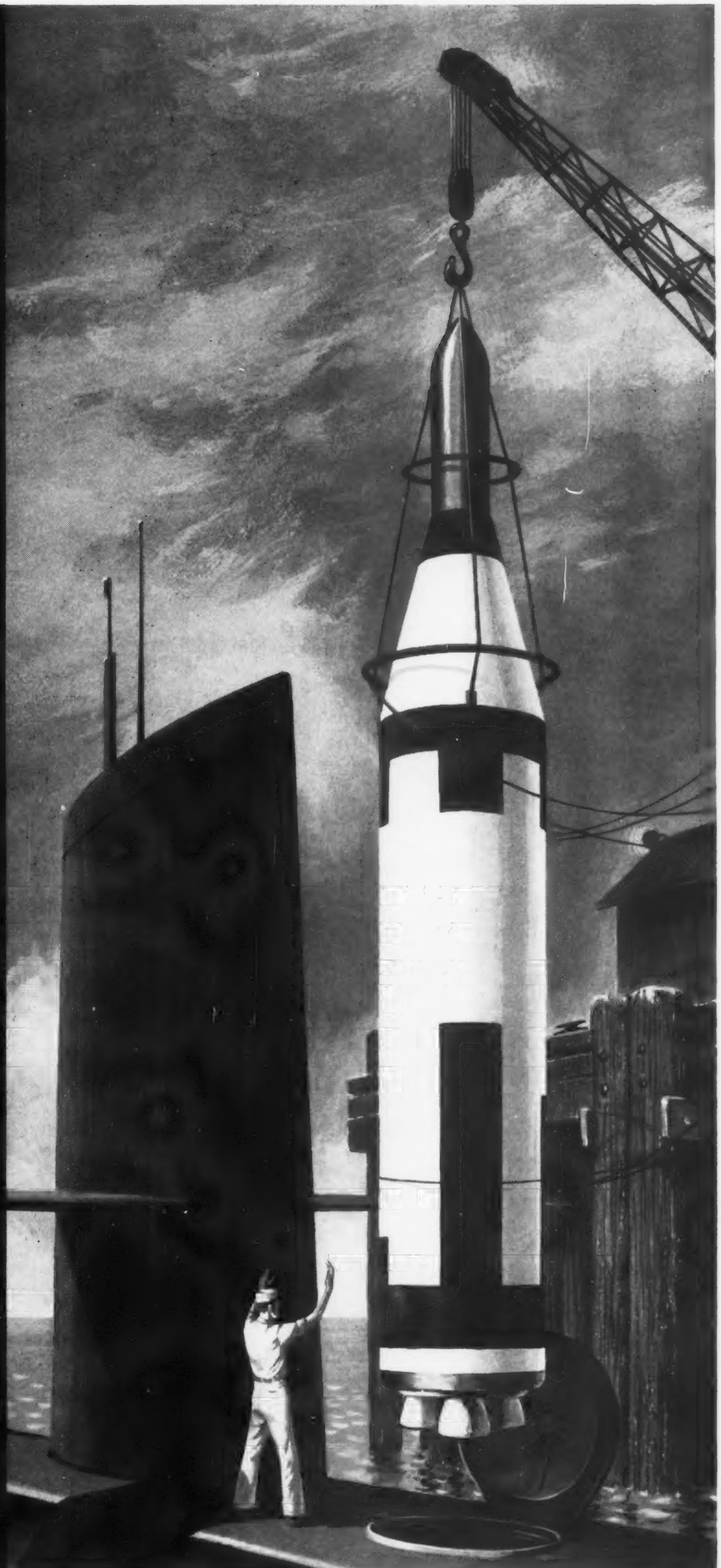

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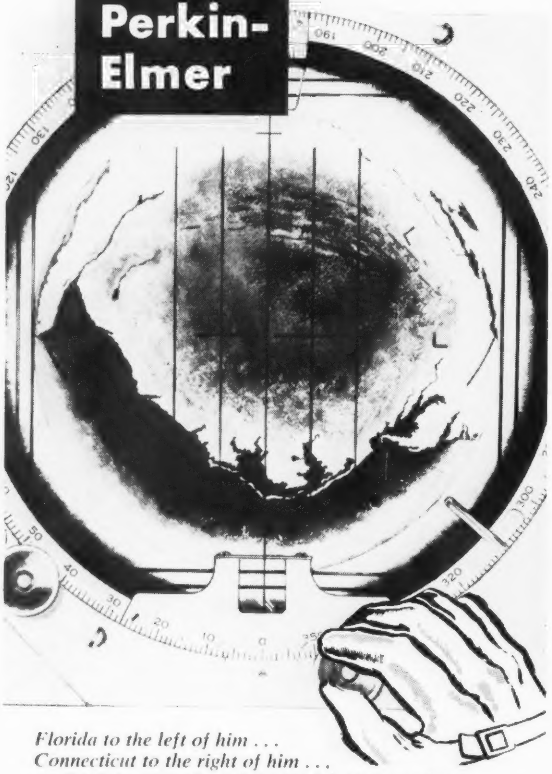

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tinued (54), a comprehensive general study was published (55, 56), a correlation based on similarity appeared (57), and experimental data for stagnation-point heat transfer (58) was presented. Studies in this area promise to provide a fuller understanding and a better basis for design in the near future.

Hypersonic flow conditions are conducive to significant gaseous electrical conductivities so that magnetohydrodynamic phenomena can be produced. The regimes of MHD were discussed (59) further during the year. Impulsive (60) and oscillatory (61) motion of a flat plate and thin lifting airfoils (62) were considered in papers appearing during 1960. Flow around a two-dimensional magnetic dipole was discussed for hypersonic conditions (63), and there were papers (64,65) on flow around a sphere. Experimental results were published for the flow around a sphere. Experimental results were published for the flow around an ablating sphere with a magnetic field affecting the flowing metal surface (66).

Progress on experimental facilities and techniques for hypersonic research also continues. Such information is often included in a publication which presents the experimental data obtained. Publications during 1960, which considered these problems only, included one on measurement of pressures (67) and another on measurement of stagnation temperature (68).

The preceding discussion indicates that considerable progress was made in hypersonics during 1960. The review has been limited to formal publications; there were also many preprints, reports, and papers. The formal publications have been categorized here to simplify reference to the original article.

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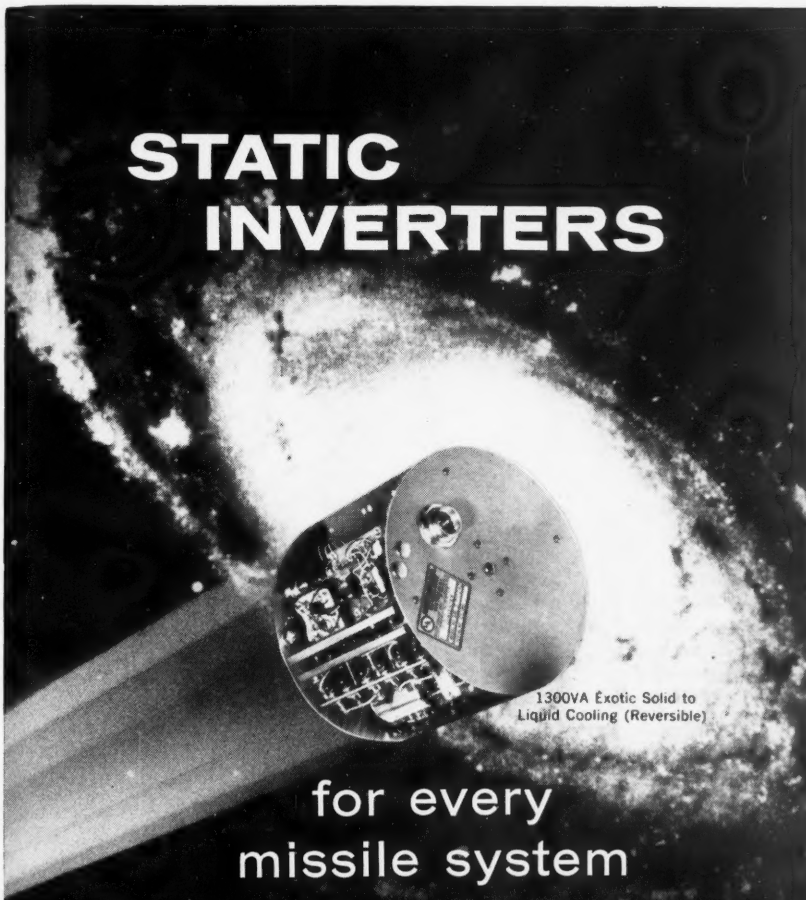

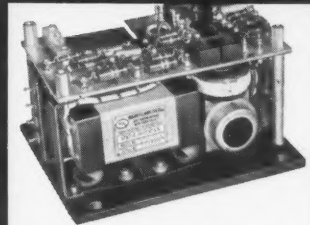
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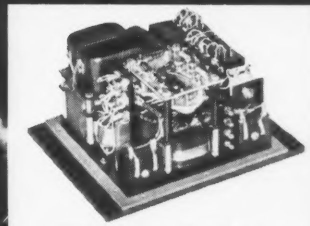
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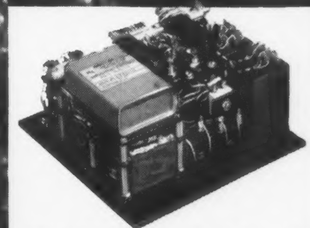
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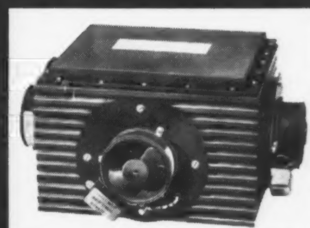
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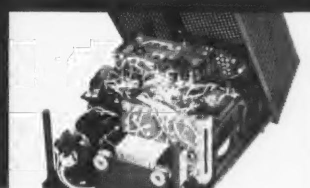
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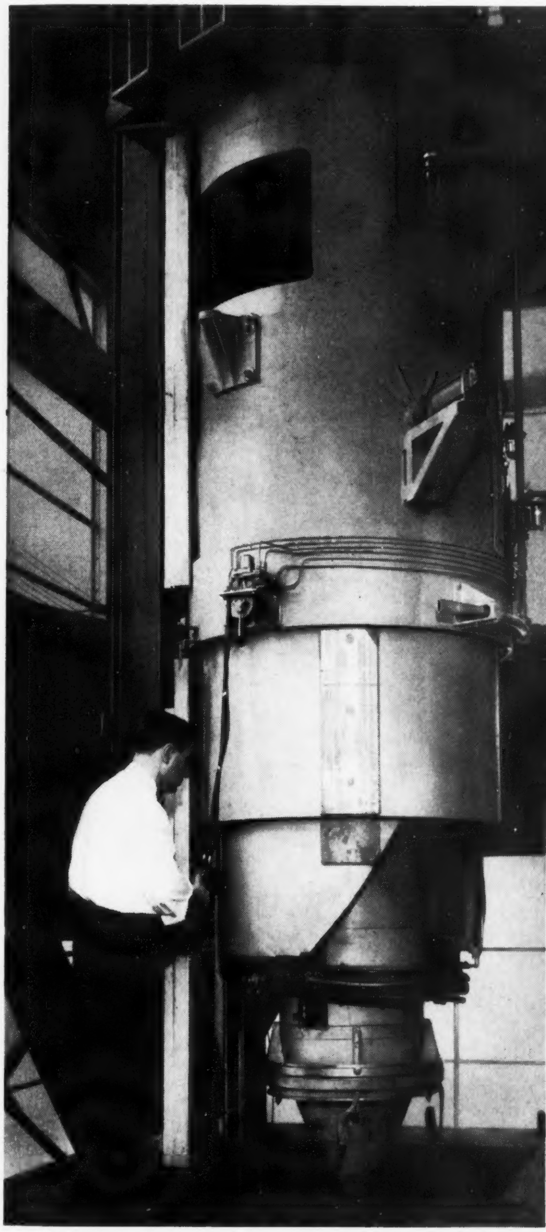
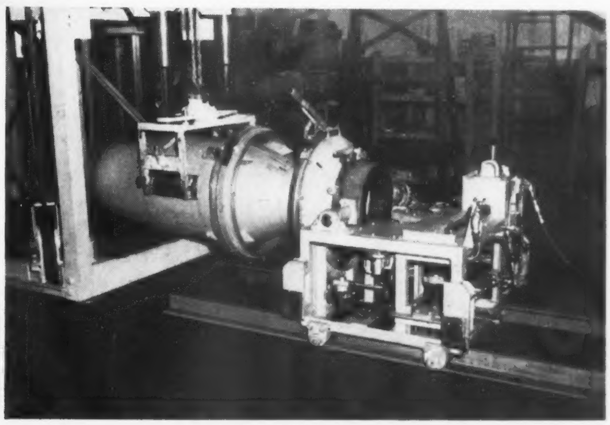


Handling hoist transferring warhead through hatch in prototype test setup for U.S.S. *Long Beach* system



Transfer of warhead from receiving stand to bi-rail trolley hoist

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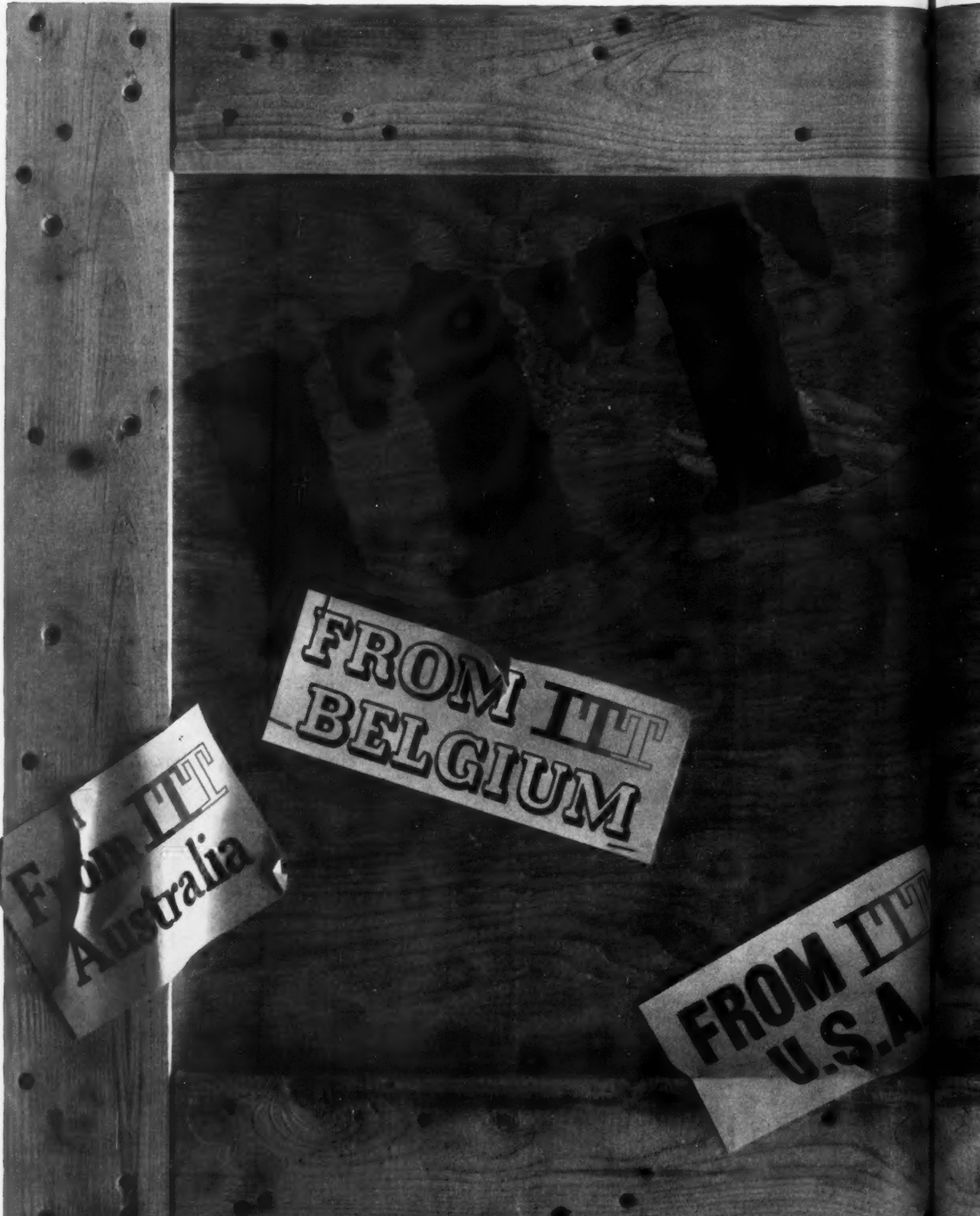

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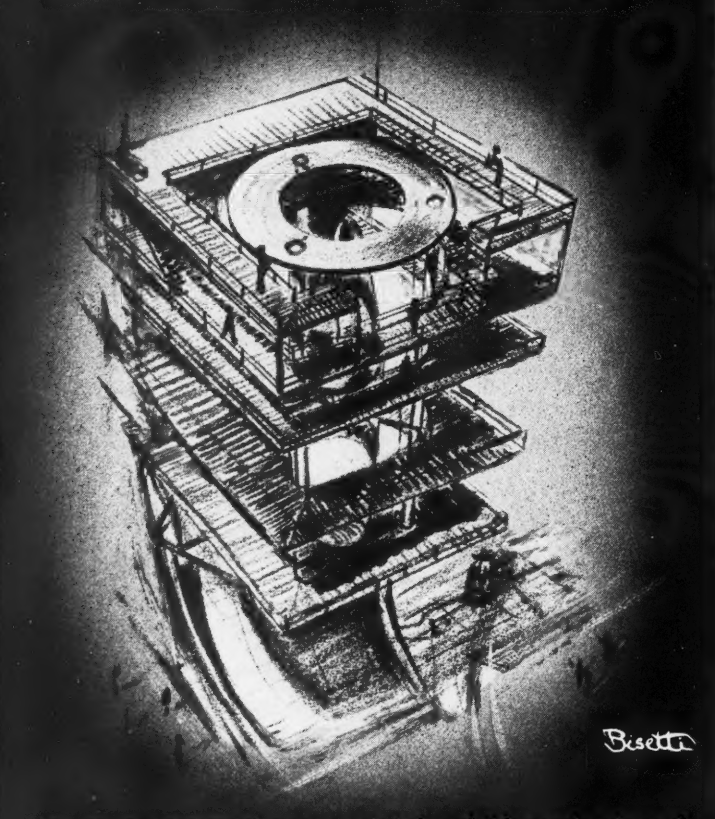

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Magnetohydrodynamics

(CONTINUED FROM PAGE 39)

provide a major stumbling block to detailed theoretical calculations, possibly even a greater difficulty than those difficulties caused by the variation in physical properties."

A perusal of the publications in the fluid-mechanical aspects of MHD indicates that the studies are primarily in the continuum regime. In general, it can be said that the cases being studied are less idealized than before and that additional geometrical configurations are being studied. In the words of Bershader (5), one aspect of MHD of considerable interest is "the existence of forward-facing waves and also forward-facing wakes in MHD flow where the Alfven wave speeds exceed the flow velocity . . ." Although experimental studies of such phenomena remain to be made, much light is being shed on the subject through the analysis of Prof. William Sears and his associates at Cornell Univ.

Magnetohydrodynamic channel flow is of immediate interest to the engineer contemplating the design of MHD devices. It is impossible to list all such studies here, but two will be mentioned. Thus, hydromagnetic channel flow has been treated by Harris (6), in his volume devoted to this configuration. The subject is receiving continued concentrated attention by Yoler (7) and his group at the Boeing Scientific Research Laboratories.

In spite of its limitations, one-dimensional flow analysis has revealed and explained many non-intuitive phenomena in classical gas dynamics which would have been too difficult to solve otherwise. In magnetohydrodynamics, too, one-dimensional flow offers many opportunities to better understand and interpret the associated flow phenomena as well as the variation of the flow properties. Such studies are in progress at Aeronutronic (8) and by this author and his students at the Gas Dynamics Laboratory at Northwestern. The latter have made the calculations for magnetohydrodynamic Fanno and Rayleigh flow, yet to be published (9).

Mixing problems are of considerable interest to the aerodynamicist. The mixing of plasmas with neutral gases in the wake or elsewhere is being studied by Goulard and his group at Bendix Products Division, and by Dennison and Hoglund at Aeronutronic (8) as well as in the Gas Dynamics Laboratory (10).

A decade ago, it used to be said that theoretical studies in hypersonics had outstripped experimental observa-

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tions. The same situation is now true in magnetohydrodynamics. This situation is dramatically brought out by the fact that whereas Alfven analytically showed (11) the existence of Alfven waves as early as 1942, they were verified experimentally (12) only last year.

MHD Experiments Scarce

Experiments in MHD are scarce because the scale of desirable experiments is usually prohibited by laboratory size and because of the very high temperatures, and the rapidity of the associated phenomena, together with the electromagnetic effects, complicate very greatly the design of instruments. Undoubtedly, these difficulties will be overcome in the not-too-distant future by a concentrated effort on the part of specialists from different fields working cooperatively and supported by respectable sums of money.

In the area of the aerospace sciences, the two predominant tools used in observing magnetohydrodynamic phenomena are the various flow tunnels utilizing a plasma generator and the multifarious shock-tube configurations. Although, in the past, research facilities were usually homemade or at least custom built, it is now possible to purchase commercially, or so to speak "off-the-shelf," research facility components. The Thermal Dynamics Corp., Avco, and Plasmadyne offer a variety of plasma generators, while Avco, Allis Chalmers, and MHD Research Inc. will provide a prospective research laboratory with complete facility systems.

Generally, the experiments being conducted in MHD fall into one of three categories, namely, fluid-mechanic observations including wave and wake formation and structure; measurements leading to the properties of magnetohydrodynamic plasmas; and the development of power generating equipment and propulsive devices. In the first category, mention should be made of the experimental study being conducted at Lockheed Missiles and Space Div. where an initial shock followed by a contact surface was identified. A time-integrated photograph taken in the Lockheed electromagnetic discharge tube is shown on page 39. Considerable research by Blackman of MHD Research Inc. for Allis Chalmers is yielding fruitful information for crossed-field acceleration in wind tunnels. Interesting aerodynamic measurements are being made by Ziemer of STL, utilizing an electromagnetic shock tube.

Much research remains to be done to confirm the theories predicting plasma properties. Thus, the properties of slightly ionized plasmas are predicted by the well-known theories of Chapman and Cowling, while for high ionization the theories of Spitzer and his associates are verified by the existing limited data. The data previously obtained by Kantrovitz, Lin, and Resler at Cornell continue to be most useful. More recently, significant data concerning the thermal and electrical properties of argon plasma have been obtained by Olson (13).

Calorimetric measurements to obtain heat-transfer data are being conducted by Jerry Grey of Princeton Univ. Attempts are being made to adapt Langmuir-type probes, but as yet the correct interpretation of the readings seems to beset the researcher. However, the theory of Talbot (14) and the experimental observations of Calcote are indeed promising.

Probably the two most promising measuring devices for plasma properties are spectroscopic techniques and microwave techniques. The former approach is being pursued by Olson and by McGregor of ARO, Inc. (operating agency for AEDC), and studies have been initiated in this laboratory by the author and his students. Among the mircowave studies may be cited the extensive work of Dougall and Goldstein at the Univ. of Illinois, as well as that at Northwestern. The photos on page 39 depict the changes in an oscilloscope trace brought about by argon plasma.

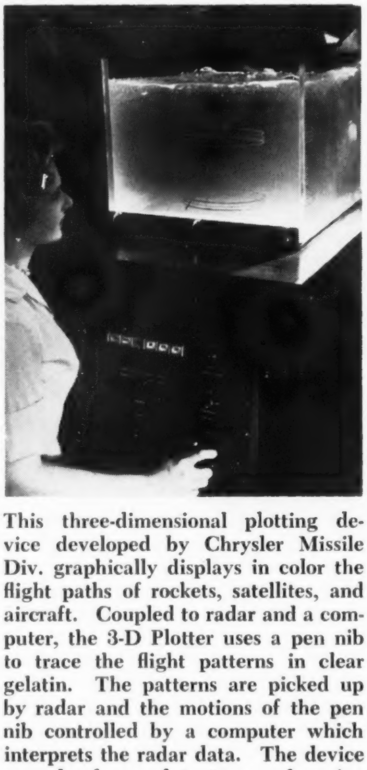
Much varied research aimed at MHD power production and plasma propulsion is in progress. In the words of Sargent Janes (16), ". . . the area which has shown the greatest degree of growth and activity is the field of magnetohydrodynamic power generation. Our experimental position is analogous to that of one who has sucessfully tested a turbine with a single blade, i.e., the present efficiency, though extremely low, is nevertheless in accordance with our calculations and therefore provides us with a significant degree of optimism about the scaling of apparatus to a size where it will indeed become efficient." MHD power generation, although still in its infancy, is most promising and is being pursued very vigorously by George W. Sutton and his group at the GE Space Science Laboratory, as well as by S. Way of Westinghouse and A. Kunen and his group at Republic.

Various schemes of MHD propulsion devices are being developed, and these are usually grouped under either of two headings, namely, electromagnetic propulsion and electrothermal propulsion. In the former category, extensive work is in progress by Bostick and his students at Stevens Institute, by the Avco group, by Meyer and Schaffer at STL, by Marshall of Los Alamos, and by Kunen and his group at Republic. Electrothermal propulsion is being developed by Mark Ghai of GE, as well as by Neuringer at Republic and by Buhler and Ducati at Plasmadyne.

Because of the extensive and varied work going on in magnetohydrodynamics, the subject has been discussed at various specialized meetings and symposia. Among the several held during the past year may be cited the Lockheed Symposium, the ARS Northwestern Univ. Gas Dynamics Symposium, the meeting sponsored by AIEE, and the AFOSR Contractors' Meeting of 1960.

It is evident that such an active field requires many competent people to pursue research. Whereas most of the present researchers did not study magnetohydrodynamics per se, there is now a university generation that just has studied or is studying magnetohydrodynamics in any of the 15 schools (17) offering such instruction. It is indeed significant that the President's Scientific Advisory Committee singled out (18) magnetohydrodynamics as

Three-Dimensional Plotting Device



This three-dimensional plotting device developed by Chrysler Missile Div. graphically displays in color the flight paths of rockets, satellites, and aircraft. Coupled to radar and a computer, the 3-D Plotter uses a pen nib to trace the flight patterns in clear gelatin. The patterns are picked up by radar and the motions of the pen nib controlled by a computer which interprets the radar data. The device can also be used to trace submarine activity, electrical and magnetic fields, and weather fronts.

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one of two subjects which should be brought into engineering curricula.

The newness of the subject is attested by the observation that there exist, as yet, no textbooks in the engineering aspects of magnetohydrodynamics. However, during the year several books have appeared dealing with magnetohydrodynamics and its various aspects. Among these should be cited "Plasma Physics" by Chandresekhar (19), "Plasma Dynamics" (20), and "Dynamics of Conducting Gases" (21).

It should be evident from this discussion that MHD is a scientific prodigy full of fascinating promises. In the words of Theodore von Karman, it truly constitutes "happy hunting grounds" for the engineering scientist. The great interest being shown in it by the government, private industry, and academic institutions indicates that its future is secure.

Acknowledgment

The author is indebted to his colleagues of the ARS Magnetohydrodynamics Technical Committee, who have been generous with their advice. In particular, he is grateful for the extensive assistance given him by Daniel Bershader, Eugene Covert, Robert A. Gross, and G. Sargent Janes.

The author wishes to take this opportunity to extend his thanks to his graduate students for the stimulating and informative discussions, as well as to the AF Arnold Engineering Development Center and AFOSR for making possible, respectively, the research in real gas physics and magnetohydrodynamics.

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Physics

(CONTINUED FROM PAGE 42)

sions of celestial sources are being conducted by NRL and NASA in an effort to understand previous discoveries of ultraviolet nebulosities and to measure the absolute luminosities of stars in the extreme ultraviolet. To date, no definite progress has been published to indicate the accomplishment of these objectives, but several important instrumentation techniques have been developed for the purpose. At X-ray wavelengths, all efforts to observe celestial sources have thus far proved negative. Much greater sensitivity is required to detect an object such as the Crab Nebula, and designs for X-ray telescopes and X-ray zone plates have been proposed to greatly increase signal-to-noise ratio.

Programs of synoptic rocket meteorology to 200,000 ft are being implemented at a number of launching sites. The experiments employ the release of radar chaff for wind studies and the Paetzold technique for ozone measurements. At altitudes near 300,000 ft, considerable effort is being expended on experiments to seed the air with tracers, such as sodium vapor, for wind studies.

Continuing observations of the drag decelerations of orbiting satellites have provided evidence for diurnal variations of atmospheric density at various altitudes. Between 200 and 250 km, density seems to vary from day to night by about 25 per cent. At 350 km density according to Priester varies by a factor of 2; at 600 km, by a factor of 6.6; and at 700 km, by a factor of 8. Kallmann has shown that these large density fluctuations at 700 km mean a 50-per cent variation in scale height from night to day and a temperature variation of 700 K.

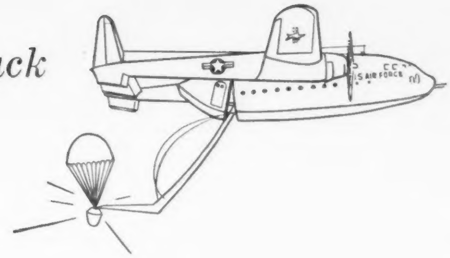
IGY Finale

Vanguard III, launched Sept. 18, 1959, was the last of that IGY Series. Its battery-operated instrumentation expired after 86 days, but its lifetime in orbit is expected to be at least 30 years. During the battery-powered interval, its proton precision magnetometer mapped the earth's field between 33.4 deg N and 34.4 deg S from 510 to 3750 km. Instrumentation to measure solar X-rays was almost continuously swamped by Van Allen belt particles, except for a small portion of the time at perigee altitudes. The experiment, therefore, did not measure solar radiation as intended, but did provide information on the structure of the lowest fringe of the Van Allen belt. Meteorite impact counters registered 3700 impacts over a 78-day period. The estimated average mass of the particles was greater than 3.3×10^{-9} gm. No punctures were observed nor was there any detectable erosion of resistance strips and optical windows.

Explorer VII, launched Oct. 13, 1959, is continuing to radio scientific data on its solar-battery-supplied transmitter. From March 31 to April 10, commencing with a great magnetic storm, the counting rate of a Geiger counter went from 200 cps down to less than 10 and then climbed to over 10,000 counts per sec. At the same time, a Geiger counter on Pioneer V barely detected any particle flux. It seems that the particles flowing from the sun had energies too low to be detected. Upon arriving in the vicinity of the earth, the first effect of the solar storm was to depopulate the Van Allen belt of its high-energy electrons. With the subsequent arrival of solar plasma, the belt was replenished and particles were accelerated locally to energies greater than 50 kev, the level at which they began to be detected by the instrumentation. At other times, interesting correlations were observed between solar activity and the stability of the Van Allen belts. For example, a great disturbance of the outer belt during a severe magnetic storm and a short intense peak (3-sec duration) over an auroral arc. Additional data were accumulated on the heavy primary spectrum of cosmic rays and on the radiation balance of the earth.

Pioneer V, launched March 11, 1960, achieved an orbit of 311.6 days period about the sun. On May 20, 1960, it had reached a distance of 10^7 miles from the earth. Four principal experiments were carried in the space probe: (1) Univ. of Chicago proportional counter telescope (threshold

finding the golden needle in the haystack



(Top right) *sketch illustrates mid-air catch of returning Discoverer XIV nose cone snagged by an airplane-towed "skyhook."* (left) *A captured practice capsule is slowly reeled towards the rear opening of airborne C-119 Recovery Plane.*

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13.5 mev for electrons, 75 mev for protons); (2) Univ. of Minnesota ionization chamber and Geiger counter (threshold 1.5 mev for electrons, 13.5 mev for protons); (3) STL magnetometer (sensitivity of a few tenths gamma); (4) AFCRC and NASA micrometer counter (responses of this detector have appeared only in large bursts, apparently because of malfunctioning of the electronics).

The March 27–April 6 period was characterized by high solar activity, at which time Pioneer V was about 5 million km from earth, near the plane of the ecliptic. On March 3 at 0800 UT, a strong magnetic storm began, accompanied by severe polar blackout and auroral displays and a large Forbush decrease in cosmic-ray flux. The proportional counter in the probe clearly showed a cosmic ray decrease of the same magnitude at the distance of 5 million km, proving that cosmic-ray modulation did not occur in the vicinity of the earth's magnetic field.

On April 1, 1960, a class 3+ flare occurred and simultaneous observations of protons and electrons from the sun were recorded both in the probe by the Univ. of Minnesota instrumentation and on the earth by polar-cap absorption of cosmic radio noise. The simultaneity of the events implies a direct path of solar particles to earth without storage in interplanetary or solar magnetic fields.

Under a Quiet Sun

The Univ. of Chicago instrumentation detected Bremsstrahlung on many days when no solar activity was indicated, revealing a solar mechanism for production of relativistic electrons, even in the absence of flares. On several occasions associated with magnetic storms, electron flux measured by Pioneer V at great distances was only 10^{-4} of that observed in the outer Van Allen belt. It may be concluded that there must be a local acceleration mechanism near the earth which creates the higher energy electrons from those arriving in the solar plasma cloud.

The STL search coil detected an undisturbed field in interplanetary space measuring 2.5 gammas. This field appeared to be tilted about 45 deg to the ecliptic. At the beginning of solar activity, the field increased on occasions to 40 gammas. A ring current appears to exist at about 10 earth radii and may carry 5 million amp. The ring is about 12,000 mi thick and the current flows westward around the earth. This reduces the intensity of the earth's magnetic field on the side toward the sun and reinforces it on the far side. Since the ring current was not detected by the high-energy particle counters it must be composed of low-energy particles. A region of magnetic turbulence was detected at 10 to 15 earth radii.

The television system of Tiros I demonstrated the feasibility of mapping cloud cover on a global scale. The intended trajectory was achieved with high precision. Burnout velocity was within 10 per cent of desired value and the ideal circular orbit was approached with an eccentricity of only 0.0045. Initially, the payload was spinning around a nearly vertical axis at about 136 rpm, much too fast for unblurred picture formation. The spin was slowed to about 12 rpm by releasing weights attached to long cables and allowing the cables to slip free of hooks after full extension. This was followed by the release of weights sliding along rods within the satellite to serve as precession dampers. The Tiros cameras took two exposures per minute which were stored in a memory device and read out on command.

Tiros has yielded some highly encouraging results. Weather Bureau meteorologists have previously had to be content with less than one-fifth coverage of the earth at any given time. The Tiros pictures with their greater coverage show an unexpectedly high degree of large-scale organization and cloud patterns.

Although Transit IB is intended to provide a new system of sea and air navigation, its complement of radio transmitters provides an important means of studying the ionosphere. The payload contains two very stable oscillators housed in Dewar flasks. One oscillator regulates transmissions at 216 and 162 mc/s, the other at 324 and 54 mc/s. Simultaneous observations of these four frequencies provide information about ionospheric refraction.

Since the discovery of the Van Allen belts of the earth, there has been much speculation about the existence of similar belts in the vicinity of Jupiter. Observations of Jovian radio-noise bursts can be attributed to the synchrotron radiation of electrons trapped in the Jupiter magnetic field. If the particle spectrum resembles that of the earth's trapped radiation, the estimated field strength must be approximately 2000 times as great as the earth's field. Alternatively, it would be necessary for the electron spectrum to peak in the bev range, instead of below 100 kev, if the magnetic field were comparable to that of earth. Interferometric observations with Cal Tech's twin 90-ft dishes have revealed that the apparent size of the Jupiter source is several times the visible diameter, in further confirmation of the picture of extensive radiation belts. These observations also imply the existence of strong auroral emissions from Jupiter. In particular, the ultraviolet emissions observed from above the atmosphere may be capable of measurement with rocketborne ultraviolet telescopes.

With regard to the source of such a strong magnetic field on Jupiter, it has been suggested that a primordial field of this character may be frozen in Jupiter's metallic-hydrogen core, provided the core temperature does not exceed 800 K.

Radar echoes from the sun were obtained at Stanford Univ. in April and September 1959. Coded sequences of pulses were transmitted at a frequency of 25.6 mc/s from a 40 kw transmitter. The received data indicated the presence of echo returns at a level after detection of between 40 and 50 db below noise.

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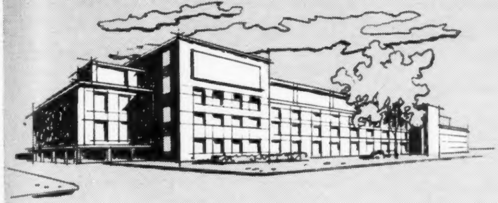

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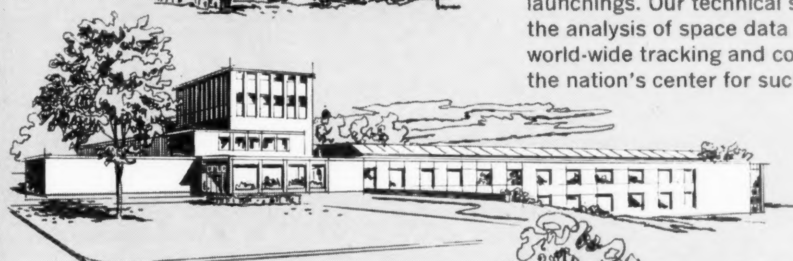

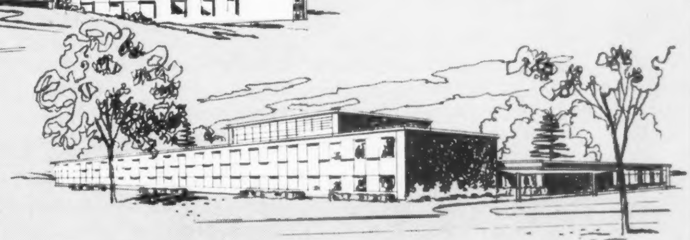

With Tiros, Echo, Pioneers IV and V, Explorer VII, and Project Mercury, Goddard has already written scientific history. Technical men who wish to work in the van of progress are invited to join Goddard or any of the other NASA research centers listed below. Address your inquiry to the Personnel Director.

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Education

(CONTINUED FROM PAGE 32)

on their own, educational programs along safe lines" in amateur astronautics, as a means of informing youth and the public of the importance of the basic sciences. In a variety of ways, and even before the Board action was taken, individual ARS members and Sections had been responding to numerous requests for lectures, demonstrations, films, and all sorts of authoritative information about space flight. Several excellent continuing programs are known to have been started in this manner throughout the country, and everywhere the volume of interest has strained the resources of the membership.

Perhaps the most spectacularly successful program is the one in the Los Angeles area, carried out in cooperation with Daniel, Mann, Johnson and Mendenhall and the Explorer Scouts, in a phased program started in May with a Space Science Exposition and continuing a month later at Vandenberg AFB, where a smaller group of 200 youngsters witnessed operations at a major launching site and again discussed specific interests with experts. Phase III is now underway, in the form of weekly lectures, demonstrations, and other programs designed for smaller class units throughout the school year.

Other aspects of the youth programs include the development of materials for lectures, demonstrations, experiments of an approved nature, and the dissemination of appropriate bibliographical material. Once again the greatest difficulty lies in giving proper recognition and circulation to the prodigious amounts of valuable material being developed in all parts of the country.

ARS Reports

Still another means of informing the general public of progress in astronautics deserves to be mentioned here, and this is the ARS SPACE FLIGHT REPORT TO THE NATION to be held in the New York Coliseum next October, at which exhibits from government and industrial laboratories will be featured which portray specific and important current developments in space technology. It may be expected that an increasing need will be felt for public presentations of this type.

In the area of collegiate astronautical programs, the peculiar and most demanding design requirements for space vehicles were early recognized as a major challenge to our engineering capability, raising questions about the suitability of traditional concepts of engineering education. Drastic revisions of existing curricula were called for, and even a thorough revamping and reorganization of undergraduate programs and pre-college training. A tendency which had started earlier, to accentuate the scientific basis and de-emphasize the more empirical aspects of engineering education, received additional impetus from various quarters. Continued development of programs along these lines is perhaps the most significant feature of the efforts which are being made by engineering educators to keep abreast of the advancing technology.

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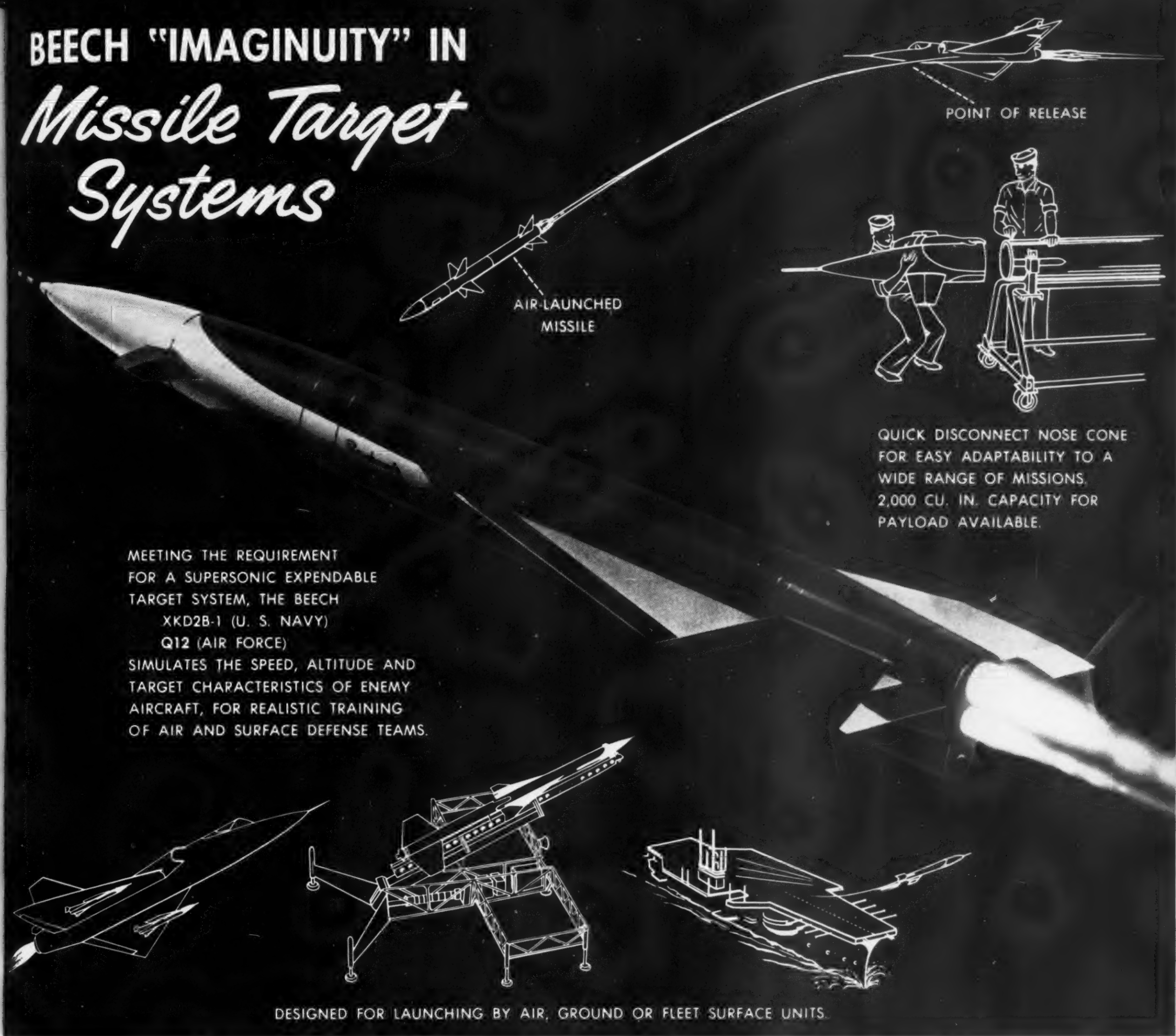
The climate for such a movement has materially benefited, moreover, from the tenor of various recommendations by officially appointed agencies and committees. The President's Science Advisory Committee, for example, composed of some of the nation's most distinguished scientists, engineers, and educators, was particularly strong in urging the goal of widespread scientific literacy among the American people at large. There are some encouraging indications that even the educationalists who dominate primary and secondary school policy are yielding their ground and beginning to comply with the spirit of such recommendations. The significance of such actions, of course, from the standpoint of better college training for engineers, is that future students will be better qualified than in the past.

Astronautics in Colleges

Almost two years ago, ARS conducted a survey of accredited engineering colleges for the purpose of determining the extent to which instruction and research opportunities had been created in engineering and science fields directly relating to the profession of astronautics. Its findings have been useful in directing students to institutions that are equipped to meet the particular requirements both for diversified and highly specialized study. In view of the likelihood of continued program revisions within the colleges in the years ahead, we may expect that periodic surveys of this type will be of great value.

It is noteworthy that much less serious concern has been expressed with respect to the adequacy of current educational practices in the sciences, from the standpoint of their role in astronautics. Although we might prefer to believe that this reflects a state of affairs which is better attuned to the needs of space flight, it is also possible that the technology has merely not fully recognized ways in which a modified scientific pedagogy might greatly benefit astronautics.

In its report entitled "Education for the Age of Science," the same President's Committee identified certain areas in need of specific and urgent attention throughout the educational system, most prominent of which are curricula and content of courses and the quality and effectiveness of teachers. Although the report did not cite any particular educational levels in its implicit criticism, there appears to be no reason to believe that existing technical college programs are exempt from the indictment. Nor did the Committee suggest measures which



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might adequately meet the needs it isolated.

It must be expected that progress will be slow in dealing with these questions, and able leadership of a very high degree must be exerted if such efforts are to be kept from foundering due to the innate resistance and conservative attitudes of engineering educators. Some measures which have become widely accepted in foreign countries, and apparently have been effective in securing and maintaining high quality and standards, will probably meet with considerable opposition in the U.S. One of these, for example, which might be of considerable help, involves the establishment of academic standards on a national scale, through a system of uniform examinations administered in critical subject areas throughout the undergraduate curriculum. Measures of this type will come up for serious consideration in the years just ahead, and the future quality of our educational system may well depend on the reception they encounter.

The loudest voices of protest against educational practices have been directed at elementary and secondary schooling, with criticism of our colleges and universities seemingly more restrained and also more limited in circulation. If we know that higher education is not really that much more perfect, we come to realize that the livelier interest in the lower levels of education must be attributed to other reasons. For example, far more individuals feel qualified to pass judgment in this area, and vastly greater numbers of students, teachers, schools, and dollars are involved.

There must be other reasons as well but the main point here lies rather in the further extension of thought: Educational needs at the more advanced levels have to a large extent escaped general notice. This is unfortunate, because no particular interest at all seems to have been generated in meeting needs in this quarter which are very real and very important. The astronautical engineer or scientist, strained to the utmost of his technical ability in the midst of this most exciting and demanding space business, is really the forgotten man when improved educational facilities are being sought.

The advanced character of his assignments, the strongly science-oriented nature of space technology, the increasingly interdisciplinary nature of the goals and methods—all these factors contribute to the individual's personal problem of continually advancing his technical competence and combating his otherwise early professional obsolescence. To meet the need, there have been in recent years many more conferences and meetings, a greatly increased volume of published literature, and an unprecedented number of advanced short courses, organized special seminars, and in-house technical lectures and discussion programs.

The usefulness and effectiveness of so many meetings has been questioned, and admirable efforts are being made to plan and coordinate them better, but still we must wonder whether these mild measures are really adequate in view of the vast technical challenges confronted in astronautics today. It may be in order to take stock of all present and known methods of upgrading and "re-tooling" our scientific manpower, and to ask whether more drastic steps are indicated. Consolidation of professional society efforts on a broad scale is being increasingly urged, and may offer distinct advantages. Possibly our supported research programs, greatly enlarged in conception and liberalized further in practice, would also meet the purpose.

A real need may also exist for the establishment of institutes for advanced space studies (somewhat analogous to existing institutes, and in other respects similar to the War Colleges) to provide for the select and mature engineer-scientist an opportunity for full-time advanced study in the latest aspects of the allied fields of his special interest. We can foresee major benefits in such plans, not only for the individual and his laboratory, but also for the national effort. ♦♦

Space Law and Sociology

(CONTINUED FROM PAGE 46)

mentality intended to depart from earth and to operate in outer space; (b) any such instrumentality which is intended to return to earth?

2. What should be the legal status, including nationality, of (a) rocket vehicles, space vehicles, or any other type of manmade instrumentality intended to depart from earth and to operate in outer space; (b) any such instrumentality which is intended to return to earth?

3. Can individual nations obtain sovereignty over celestial bodies?

4. What acts are necessary to establish the sovereignty of a nation over a celestial body? For example, what would be the legal effect of contact between (a) a manned space vehicle and a celestial body; (b) an unmanned space vehicle and a celestial body?

5. What is the extent of sovereignty over a celestial body?

6. How far does the sovereignty in a celestial body extend beyond the physical substance of the body?

7. What theories have been advanced by recognized commentators as to property rights in celestial bodies?

Working Group 3

1. What theories have been advanced by recognized commentators as to sovereignty over celestial bodies?

2. What should be the legal status of the sun, the moon, the planets, and other natural objects in outer space?

Working Group 4

1. As to each terrestrial sovereign nation, state the treaties to which such nation adheres, and its domestic laws, rules and regulations concerning airspace and outer space, and those treaties, laws, rules and regulations which would have to be amended, revoked, changed or superseded because of the adoption of any treaty, law, rule, or regulation.

2. What new situations in the area of domestic law are created by space activities to which existing laws are not applicable?

3. Should national codes of domestic law be developed to meet problems arising out of space activities? For example, should those nations which hold themselves to be immune from suit by reason of sovereign immunity permit suit against themselves in the case of actions arising out of space activity?

Working Group 5

1. What should be the nature and scope of regulations governing the following aspects of space flight?

(a) Registration requirements for public and private space vehicles

(b) Inspection of space vehicles before launching

(c) Air traffic rules to be followed by spacecraft while passing through airspace and through outer space. In particular, what regulations should be made to cover:

(i) Announcement of proposed space-vehicle launchings, together with information on the vehicle's trajectory

(ii) The passage of vehicles in outer space so as to avoid collision

(d) Safety of life and property in airspace and in outer space

(e) Search and rescue

(f) Emergency landing of spacecraft

(g) Emigration and immigration

(h) Prevention of contamination of airspace and outer space [e.g., by atomic radiation, refuse, abandoned vehicles, and the like]

(i) Prevention of contamination of earth and celestial bodies

(j) Collection and dissemination of information as to the weather, radiation, meteorite activity, and similar conditions encountered in space flight

(k) Are space vehicles allowed to take and release pictures and television films? If not, what are the remedies of states overflown?

Working Group 6

1. Are existing international organizations able to administer and enforce appropriate regulations which may be adopted for the regulation of activities in space? If not, is it feasible (a) to adapt existing international organizations so that they would be able to administer and enforce appropriate regulations, or (b) to create new international organizations to administer and enforce such regulations?

2. What authority should be delegated to the international organization or organizations which would be responsible for the administration and enforcement of space regulations?

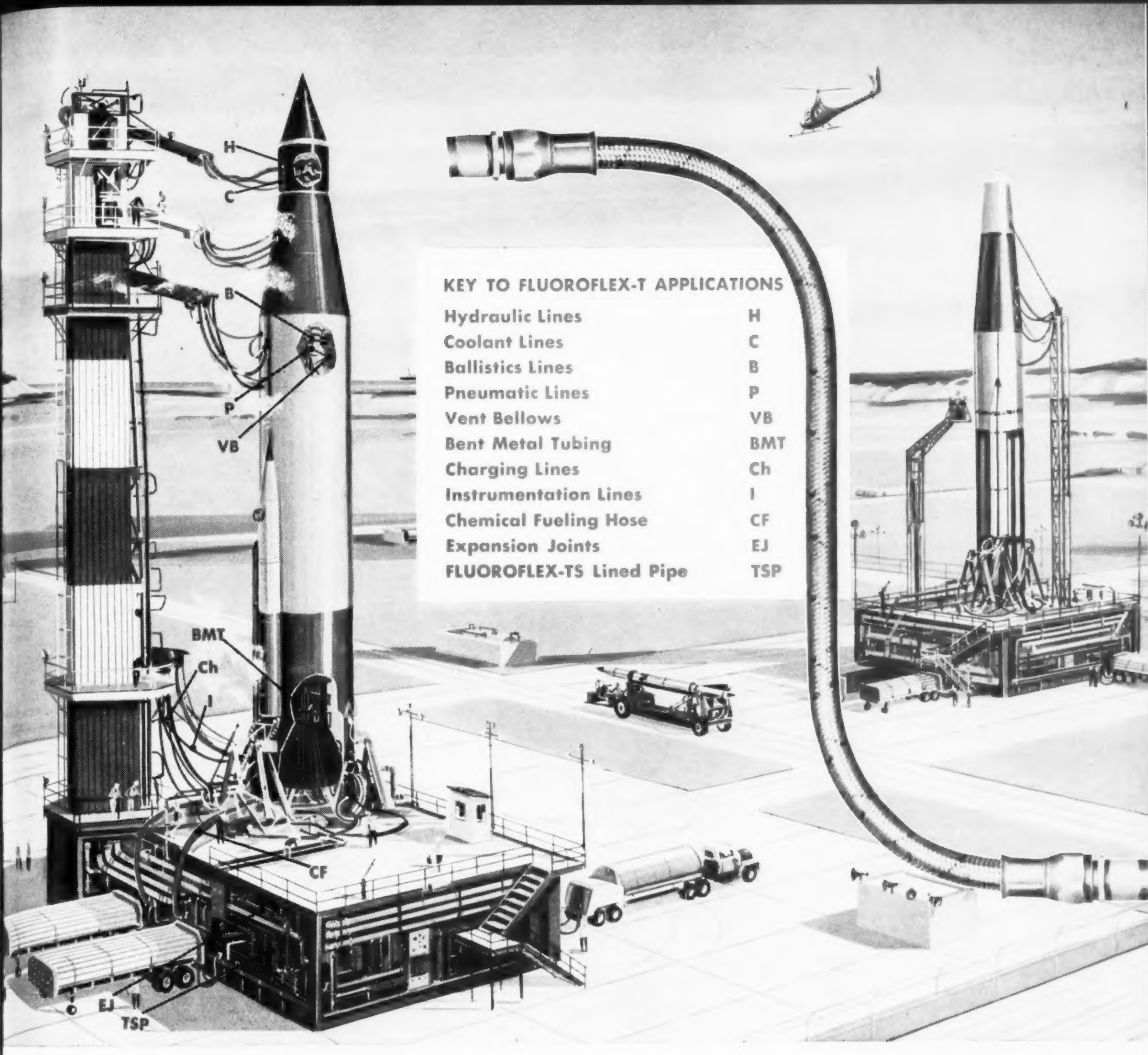
3. What provisions for arbitration should be included in any international agreement concerning the use of airspace and outer space? What situations, if any, should be subject to compulsory arbitration?

4. What is the present and potential role of the International Court of Justice in the settlement of legal problems of space activity?

Working Group 7

1. What provisions should be made for the determination by national and international organizations of the nature and extent of the requirements for the use of radio in space flight activities? What is the status of current knowledge as to the extent of such requirements at present and in the foreseeable future?

2. What provisions should be made for the determination by national and international organizations of the radio frequencies available for use in space flight activities? What is the extent of current provisions in national and inter-



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national law for allocations for such uses of radio frequencies?

3. What provisions should be made for international agreement on interference involving radio frequencies used in space flight, including the following subjects:

a. Interference to radio transmissions in space flight activities

b. Interference from radio transmissions in space flight activities to other uses of radio

c. Termination of transmissions from radio transmitters in space, especially those operating unattended

d. Establishment of priorities for transmission and reception involving space flight activities where interference would result from simultaneous transmissions from several sources

e. Identification of transmissions to aid in the determination of the sources of transmissions and of interference

4. Is the International Telecommunication Union [ITU] presently constituted so as to be capable of regulating the use of radio in space flight activities? To this end, what are the present legal capabilities of the ITU with regard to the matters listed below, and in what respects should the International Telecommunication Convention and the Radio Regulations of the ITU be enlarged, or modified, so as to permit the resolution of these issues?

a. In what manner should radio frequencies be allocated for use in space flight activity, i.e., on an exclusive basis, on a shared basis involving other uses, to individual nations, to world organizations, and the like?

b. What is the extent of the ITU's jurisdiction? Can frequency allocations be enforced by the ITU as to uses outside the earth's atmosphere?

c. Are the existing agencies of the ITU capable of making continuing studies of the uses of radio in space flight activities? In what respects should the agencies of the ITU coordinate such studies with other bodies such as the IAF?

Working Group 8

1. What situations are created by space activities affecting private rights, to which existing treaties, conventions, agreements and laws of sovereign nations are not applicable? Specifically, what effect will space activities have upon private rights and duties in the following areas: Nationality, citizenship, customs, domicile, crimes, immigration, emigration, ownership of property, torts, contracts?

2. What regulations should be adopted for the protection of private interests or for national proprietary interests in outer space?

3. What types of international forums or adjudicatory bodies should be set up by international agreement to decide upon the liability, and the extent of the compensation applicable, in case of any violation of private rights caused by a space flight activity?

Working Group 9

1. With specific reference to damages caused as a result of space flight activity, what provisions should be included in international regulations or agreement governing the establishment of responsibility, and rights of recovery for injury or damage caused by space vehicles

a. To property and life on the surface of the earth

b. To airborne property and life

c. To space vehicles and property and life contained therein?

What should be the basis of liability for such damage? In particular, should liability be based upon a theory of gross negligence, reasonable care, strict liability, or some other rule?

2. What requirements and instrumentalities should be created through international agreement to assure the compensation of individuals entitled to relief for any violation of private rights? In connection with this question, will financial guarantees of sovereign states suffice? Would compulsory insurance suffice? Should a specific compensation fund of an international character be created to which public and private agencies would be required to contribute in advance of any form of space flight activity?

Working Group 10

1. What international organizations, governmental and nongovernmental, are presently concerned with the regulation of space activities?

2. To what extent may these existing organizations (such as the IAF) serve as agencies for the regulation of various activities in space?

3. Should new international organizations be established for the promotion and coordination of activity in outer space?

4. Should a committee be formed to draft an international agreement, modeled on the Antarctic Treaty of December 1, 1959, to limit the use of outer space to peaceful purposes?

Working Group 11

What arrangements should be made for the creation of international agreements covering

(a) Cooperation in space exploration

(b) Prohibition of the use of artificial satellites and celestial bodies for certain purposes

(c) Cooperation in the development of space law

(d) Provisions that space problems not covered by existing law be settled by negotiation or arbitration

(e) Establishment of methods for dissemination of basic scientific data regarding space flight

(f) Establishment of space-data centers and research institutes

(g) Operation of international satellites and space platforms

(h) Prompt return to the launching country of space vehicles, their equipment and personnel which have landed or crashed on the territory of another sovereign state

(i) Use of satellites in charting aids to ship and aircraft navigation

(j) Inspection and control of armaments on space flights, particularly nuclear weapons, as well as controls suggested for policing the peaceful uses of atomic energy

(k) Adoption of an "International Space Navigation Code," analogous to the "International Code of Signals on the High Seas"

On the occasion of the ARS 15th Annual Meeting in Washington, D. C., next month, outstanding authorities in many of these fields will discuss in authoritative detail solutions to the many problems set forth here.

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Underwater Propulsion

(CONTINUED FROM PAGE 49)

sion, particularly those of turbomachinery, such as turbopumps for liquid rockets, or for various functions in thermal powerplants. These have principally the same problems as the hydrodynamic propulsors of submerged bodies. In both fields the need of low weight, combined with high reliability, is of critical importance. This leads to parallel considerations regarding mechanical construction, principles of arrangement, and choice of speed. Most of all, both fields share the problems of cavitation, which limit the speed of hydrodynamic machinery, thereby setting lower limits for the size and weight of equipment required to perform a certain task. In both fields operation without as well as with cavitation must be considered.

Another area in which the underwater and astronautical fields are found to have similar requirements is, surprisingly enough, that of external fluid-dynamic forces. These forces are the same in air at sea level and in water if the velocity in air is about 30 times that in water. When compared with flight at great altitudes, this factor may reach values of a hundred or more. Forces encountered during flight through the earth's atmosphere thus are of the same order as those experienced by bodies traveling through water. This resemblance can become even closer if we compare a liquid rocket with a submerged tanker of the future, as the ratio of structural weight to the weight of the liquid may reach values with the tanker almost as low as those used today with liquid rockets. Thus the aeroelastic or hydroelastic problems of these two fields may occasionally be very similar indeed. It is therefore to be expected that the fields of astronautical and underwater propulsion will be found to share many scientific and technical interests and to develop close ties. ♦♦

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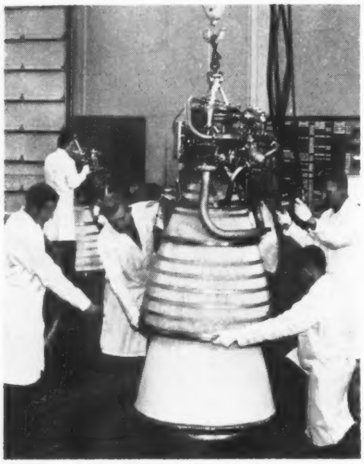

Technicians at Pratt & Whitney Aircraft's Florida Research and Development Center prepare the nation's first hydrogen-oxygen rocket engine (LR-115) for shipment from West Palm Beach to Cape Canaveral, where Convair will static-test it in preparation for Centaur free flights. The LR-115, first models of which will deliver approximately 15,000-lb thrust, has been designed for starting and stopping several times in space, thus making possible efficient placement of satellites in orbit and deep-space probes on trajectory.

Thinner and Stronger

The technician is spot-welding multi-ply-wound thin strips of precipitation-hardened AM-355 stainless steel into an experimental solid rocket motor case that will take a hoop stress of 305,000 psi, or about 30 per cent higher stress than a single-thickness case of low-alloy steel. Ryan Aeronautical of San Diego has built and tested several experimental cases in this promising fashion. Allegheny Ludlum developed the AM-355.

Progress in Space Flight

(CONTINUED FROM PAGE 25)

tions in the U.S. and voice transmission has been made successfully between the Bell Telephone Laboratory at Holmdel, N. J., and the Jodrell Bank antenna in Manchester, England. These experiments demonstrated the feasibility of using passive satellites for point-to-point communications throughout the world.

In October 1959 NASA circulated a brochure describing Project Echo, both throughout the U.S. and in foreign countries. The intent of this brochure was to encourage independent use of the Echo satellite. Many independent experimenters have made use of Echo, and have contributed significantly to the wealth of data already accumulated with it.

Although Echo I is now believed to be somewhat wrinkled, recent repeat experiments of early transmissions have revealed no loss in message quality, and experiments will continue throughout the "as yet unknown" life of the satellite.

Because of a low structural density, the orbit of the Echo satellite is strongly influenced by drag and solar radiation pressure. Interesting scientific results on these effects have already been obtained.

Pioneer V, launched on March 11, 1960, contributed an impressive record of findings during its useful life of 107 days. During the 139 hr of data transmission from a farthest distance of 22.5 million mi, Pioneer V transmitted 3-million binary-coded bits of data. Analysis of the observations from Pioneer V have provided new information about cosmic rays, radiations associated with solar flares, and the magnetic field in interplanetary space.

Shortly after its launch, when Pioneer V was about 5-million km from earth, solar activity increased greatly with the occurrence of numerous flares, radio noise bursts, and associated terrestrial effects, such as geomagnetic disturbances, auroras, and variations in both galactic and solar cosmic-ray intensities. Fortunately, it was possible during this period to correlate measurements from Pioneer V with similar instrumentation on Explorer VII, which is still transmitting data, and with ground and balloon-borne instrumentation. From these correlations the participating scientists have derived new concepts of the environments of outer space. These concepts are expected to lead to the establishment of new theories and in some cases to the invalidation of old ones.

The technological developments in Pioneer V have established a new level of performance from which future interplanetary spacecraft will advance.

During the remainder of this year, in 1961, and in the years ahead, the NASA will continue its broad and comprehensive program of space exploration with specific objectives that may be briefly expressed as follows:

1. To produce scientific data on the space environment, the sun, earth, and planets, and the galaxy, using unmanned spacecraft equipped with instrumentation and telemetry to relay data to the ground. This information is essential to all utilization of space and to an understanding of the physical universe and its relation to man.

2. To study early applications of earth satellites to meteorological research and weather forecasting, long-distance wide-band radio communications, navigation, and similar tasks.

3. To explore problems of manned space travel, at first in orbital flight about the earth for short periods, later in flights to the moon, and still later to the planets and outer reaches of the solar system. The pace of manned exploration will be determined largely by the results obtained in the early orbital flights.

New Vehicles Coming

In the program of scientific satellites and probes, a new generation of spacecraft is currently under development. Of larger size than the Explorer VII and Pioneer V spacecraft, they will embody new design principles leading to greater flexibility, reliability, and economy. Utilizing repetitively the same structures, power supplies, and telemetry systems, the spacecraft are being designed to accommodate different scientific experiments in a series of launches.

Three new scientific satellites of this type, designated as observatories, are included in the advanced program. The Orbiting Solar Observatory, which is scheduled for flight in 1961 with a weight of about 350 lb, is designed to point toward the sun and measure solar phenomena. Initial instrumentation for this satellite includes X-ray and ultraviolet spectrometers.

The second series of satellite observatories is called the "Orbiting Geophysical Observatory." These satellites, with a weight of about 1000 lb, will be instrumented variously for measurements of the atmosphere, the ionosphere, the earth's magnetic field, and other geophysical phenomena, and will be flown in different orbits around the earth.

A third series of Orbiting Astronomical Observatories will weigh about 3500 lb and be about 10 ft in diam.

These satellites will be able to make precise telescopic observations of the emission and absorption features of the stars, planets, and nebulae. They will have precise stabilization and pointing controls with command operation from the ground.

The OGO (Orbiting Geophysical Observatory) and the OAO (Orbiting Astronomical Observatory) are currently in the contract phase and will take several years for development.

In continuing our scientific investigations of the moon, the planets, and interplanetary space, several new spacecraft are in preparation for flight and others are in early design stages.

This year our program includes the launch of a lunar orbiter with a weight of about 400 lb. Rocket engines and propellants for mid-course and terminal maneuvers and eight geophysical experiments are included in the spacecraft.

Currently under construction for launch in 1961 are the first of the Ranger series of spacecraft, which will continue NASA explorations of the moon and early exploration of interplanetary space. The lunar and early interplanetary spacecraft of the Ranger type will be launched with the Atlas-Agena vehicle, while the series called Mariner, for later planetary flight, will use the Centaur launch vehicle.

Studies, designs, and developments on the follow-on spacecraft for the lunar and interplanetary missions have already begun.

A lunar soft landing spacecraft called Surveyor is planned for launch with the Centaur vehicle. Later the Saturn vehicle will be used to launch a heavier mobile spacecraft called Prospector for lunar surface exploration, and to launch planetary probes and orbiters.

Flight operations in NASA's manned space flight program will reach a peak activity during the coming year.

This year the X-15 airplane, the product of ideas initiated in 1952, set new records for speed and altitude. In August 1960, Joseph Walker piloted the X-15 to a speed of 2196 mph ($M = 3.31$) faster than man has flown before; and in the same month Major Robert White, USAF, piloted the X-15 to a new altitude record of 136,500 ft. As a forerunner of manned space flight, the X-15 is providing useful data on problems of supersonic aircraft stability, re-entry heating, instrument displays to the pilot, and pilot response to fast-changing situations.

Project Mercury, which is an initial step toward providing the capability for manned exploration of space, is currently moving at a rapid pace through the development and construction phases leading to manned orbital flight.

Developing the Mercury capsule has required major technical advancements in many fields, such as aerodynamics, aerospace medicine, instrumentation, communications, controls, life-support systems, and landing techniques. The Mercury program includes flights to check capsule reentry, recovery techniques, the abort system, and flights to qualify the entire system. In a few months, manned ballistic flights are scheduled as part of this qualification program. Manned orbital flights will be made as soon as all elements of the Mercury system are qualified.

Apollo Formulated

Even as we build toward the first manned flight, we are busy preparing for the next step. Design studies will be contracted with industry this year to determine the most feasible way of building a dual-purpose spacecraft that can be used as an earth-orbiting laboratory or to circumnavigate the moon. This project, called Apollo, is a logical intermediate step toward

"... Where there is no air to resist their motions, all bodies will move with the greatest freedom."

SIR ISAAC NEWTON *Principles of Natural Philosophy*

Today, almost three hundred years after Newton's *Principia* appeared, man is about to satisfy his centuries-old curiosity concerning space "where there is no air." First instruments went. Soon man himself will go.

Prior to man's undertaking sustained space voyages propulsion systems with efficiencies far exceeding those presently available must be developed.

The scientists and engineers at Electro-Optical Systems are in the advanced stages of research and development on what may well be a forerunner of practical space propulsion systems — the ion engine.

Other advanced research and development programs in areas vital to technological progress in space, military weaponry and industry include:

Energy Conversion Research and Advanced Power Systems
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future goals of landing men on the moon and nearby planets.

International programs, endorsed by the Congress in the National Aeronautics and Space Act of 1958, will assume greater definition during 1961. The first of several satellites to be instrumented by scientists abroad is scheduled to be launched in the latter part of the year. In addition, ground-based programs in support of satellite experiments will be encouraged on the part of scientists abroad. Useful supplemental and correlative data may be expected.

Sounding Rockets Up

Joint sounding-rocket programs, organized with Italian and other scientific groups, are scheduled to be carried out abroad in 1961. In all, nearly one-half of the sounding-rocket activity planned by NASA for 1961 will take place at launching sites in other countries, notably in Canada. Some of these launchings will be scheduled to coincide with the synoptic programs planned by the International Committee on Space Research (COSPAR) for specific international rocket intervals.

NASA also expects to provide laboratory support to foreign scientists sponsored by their governments for the purpose of acquiring some know-how in space science activity. Japanese, French, Italian, Argentine, and Swedish space groups have already indicated their desire to utilize this opportunity during 1961. A training program is directed also toward expanding the participation of foreign nationals in the operation of NASA overseas tracking and communications facilities. Finally, associateship grants for postdoctoral scientists, enabling them to pursue space-connected interests in NASA laboratories, will continue through the National Academy of Sciences.

During the year, the NASA strengthened its team for conducting the space research and exploration program. Late last year the growth of the space program led to the establishment of a separate launch-vehicle directorate under Maj. Gen. D. R. Ostrander. The NASA team was greatly enhanced by the addition of the Marshall Space Flight Center at Huntsville in July of this year. This Center, headed by Wernher von Braun, will concentrate on the development and launching of major NASA launched vehicles. The development of the Centaur and Saturn launch vehicles, which are vital to the entire space program, is a responsibility of the Marshall Center. The NASA effort in the life sciences has been strengthened by establishing a directorate in this field headed by Clark Randt.

Progress during the past year has been rapid, but formidable problems lie ahead as more difficult flight missions are attempted. Creation of the new space science and technology will require the wholehearted support of all who are qualified to contribute. ♦♦

"Big Sticks" of Space Age

(CONTINUED FROM PAGE 29)

little in the way of ballistic-missile technology or hardware. The challenge facing the AF Ballistic Missile Div. then was the development of an intercontinental ballistic missile. It was a single objective, but multiple in terms of the technological problems to be overcome. The Strategic Missiles Evaluation Committee, that august body of eminent scientists and physicists who set the stage and laid down the blueprints for the original ballistic-missile development effort, advocated production of an ICBM of a specified warhead yield, capable of a 5500-n. mi range, with an accuracy radius of five miles to target. They predicted that the missile, already labeled the Atlas, could be produced to those plans in six to eight years.

The record shows that Atlas was produced and brought to operational status in a little more than five years, with a 6300-mi range, a higher yield, and an accuracy under two miles—better than originally estimated. During this time interval, extensive teamwork and dedicated efforts by the Army and the Navy, as well as the Air Force, gave birth to other major ballistic-missile-weapon systems. These include the AF Thor, Titan, and Minuteman, the Army Jupiter and the Navy Polaris. At the same time, a broad assortment of significant accomplishments in space have been recorded.

At this point in time, and based on the successes of our programs to date, it appears that there are two dominant yardsticks that must be applied in the judicious disposition of our present and future ballistic-missile and space-vehicle resources.

First, 20th Century defense cannot measure up to the challenge at hand unless that defense is represented by a versatile, stalwart military force posture that assures true deterrent strength in depth. Secondly, in building and maintaining a defense system of this nature, the U.S. must be economically prudent in the choice and use of weapons.

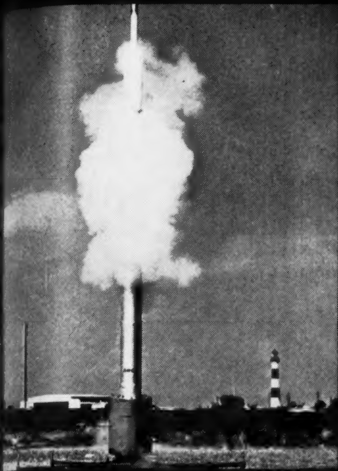
The U.S. does not have an unlimited budget. Neither does the Soviet Union. There is no denying that America can afford what it must afford. But to give serious attention to price tags, without taking into account what those tags represent, can result in financial folly. A fleet owner does not buy limousines when it is obvious that moderately priced sedans will fulfill the requirement for utilitarian reliable transportation. The overriding economic fact of life is that, in these days of costly and complex weapons, the U.S. must seek to buy the *most effective military force for the dollar*. This is particularly important in view of the fact that Communist planning calls for undermining of the democratic system by whatever means possible—political, psychological, military, or economic.

Happily, the U.S. is a nation of great material *and* intellectual resources. We have around us today, in operation or under development, a variety of modern weapon systems which together comprise the comprehensive deterrence demanded by the world situation. In the ballistic-missile program, for example, the U.S. has built a solid foundation both in technology and in hardware. We are now at the point where we can proceed quite rapidly to obtain in quantity and quality weapons that are being bred from our vast development efforts. What seems demanded now, in a degree never before necessary, is sound judgment, enlightened foresight, and intelligent understanding of our needs and the manner in which those needs can be met most practically. There is no compromise with our individual and collective obligation: Service in the best interests of the nation.

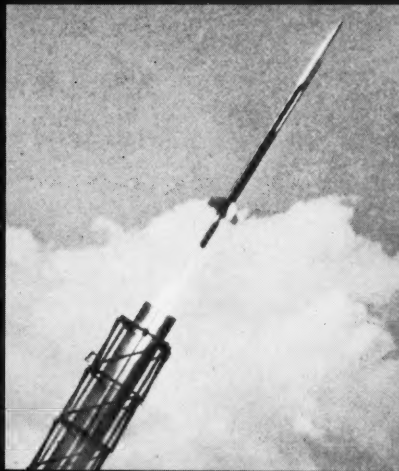
The formula for deterrence is not foolproof. The Soviets understand and appreciate mass and have a healthy respect for the value of numbers. Although numbers are extremely important, they are but one ingredient in the U.S. military formula. To achieve the deterrence-in-depth that has been mentioned above as a major requirement, our missile systems must also reflect a balance of credible cost survivability with strike effectiveness.

It should be easy to see why this is necessary. When modern weapons are measured by the yardstick of deterrent value, the degree to which any U.S. weapon is militarily effective becomes the ultimate criterion of that weapon's worth.

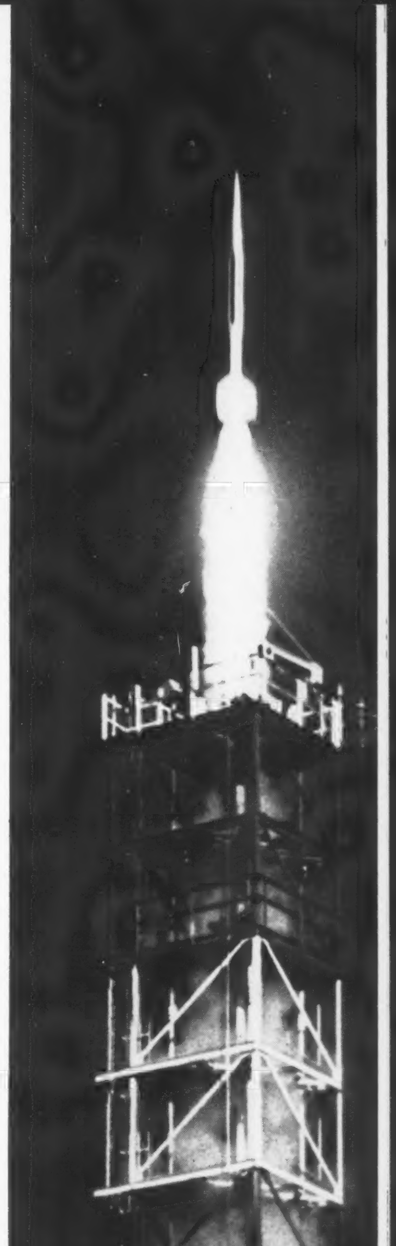
A long-range bomber on the ground is an implied deterrent, but that air-



ARCAS



ARCON / ARCHER



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- Similar to the Arcon, shown above
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- 12-pound payload
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In design of sounding rockets, Atlantic Research takes full advantage of solid propellant ***cost efficiency, versatility,*** *and* ***reliability.*** *For example, the oft-flown Arcas—over 250 flights—has demonstrated its dependability by achieving a 97 per cent record of success. More information and complete technical data can be obtained from our Development Department.*

Atlantic Research Corporation

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craft nuclear-armed and in the air becomes a much more realistic deterrent. A ballistic missile poised on an unprotected launching pad packs the same threatening punch as a missile nestled underground, but the protected bird greatly increases the enemy's targeting problem. A nuclear-powered submarine is a potent weapon when at sea and armed for missile-launching action, but the submarine in port for service is virtually defenseless against surprise attack.

A Sum-Total Strike

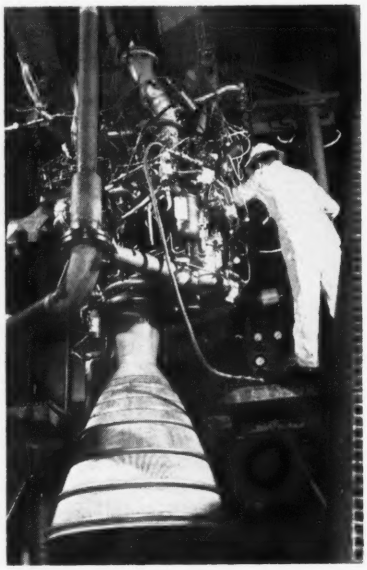
If deterrence is relative, it is also cumulative. It is not the nature or the portent of any one weapon that counts. It is, rather, the sum total striking power of our entire military force that an enemy must take into account when pondering overt action. To increase and to insure the highest possible percentage of strike power, the Air Force has given careful consideration to the matter of survivability. It is not only how many weapons we put into position, but how well we protect those weapons that determines whether our deterrence is comprehensive or shallow.

It is the recognition that this variation in emphasis can make a world of difference in our deterrent posture that has led us in the Air Force to exploit all practical ways in which we can enhance our defensive strength. With ballistic missiles, we are striving to achieve a systematic and frugal interaction of three factors—dispersal, mobility, and numbers. In doing so, we contribute as well to our requirements for credible deterrence and cost effectiveness if we also attain simplicity, reliability, fast reaction, adequate yield, and reasonable accuracy.

The importance of dispersal is self-evident. While pinpointing the location of Soviet launching sites is a challenging job for the U.S., our adversary on the other hand has no such problem. Therefore, we scatter our missile sites in unitary fashion to decrease their collective target value. When we also harden these bases, we gain economic as well as strategic advantages, for with hardening we can reduce the dispersal distances between sites. When we anticipate missile forces in number, these savings become highly significant.

Our objective is to protect our missiles from destruction by surprise attack. Because of the variables of accuracy and reliability, an enemy will have to program several missiles for every one of our weapons he hopes to knock out. When our defenses are dispersed and hardened, the number of weapons he is compelled to expend

Titan's Versatile Second-Stage Engine



A technician checks the 80,000-lb-thrust Titan second-stage engine, developed and produced by Aerojet-General, before a static firing at the company's Sacramento, Calif., facility. Besides second-stage power, this engine provides control of pitch, yaw, and roll, thrust for staging, and vernier calibration.

is multiplied—and his costs in time, talent, launch facilities, and money are likewise multiplied. Ballistic missiles are costly but expendable. However, their survivability decreases when they are positioned in such a way that 12 or 15 of them can be eliminated by a single blow.

If the present sole deterrent strength of this nation were vested in the Atlas squadrons now operational, we might have genuine cause for concern, for these first facilities are admittedly vulnerable to attack. But our basic deterrent force at this particular point in time still rests with the potent SAC bomber force. As ballistic missiles grow in numbers on the other side of the globe, the counter forces in this hemisphere are emphasizing survivability.

Introduction of dispersal and hardening factors into the Atlas build-up program is illustrated by bases now under construction at Fairchild and Forbes Air Force Bases and at the Warren III squadron. Atlas ICBM's on guard at these locations are being protected in horizontal bunkers in the "coffin" configuration, for shelter against blast overpressures.

Beginning with the eighth squadron, Atlas missiles will go underground. Steel and concrete inverted silo implacements, 170 ft deep and 54 ft in diam, will protect our ICBM's from blast pressures of well over 100 psi.

The silo concept was introduced into the Titan ICBM program in late 1957. The first six squadrons in our programmed Titan force structure of 14 squadrons are being constructed in the three-by-three hardened configuration, with the first squadron—near Lowry AFB—to become operational in the summer of 1961.

The eight squadrons rounding out the Titan defense system represent the near-ultimate in survivability through present-day concepts of dispersal and hardening. Each underground facility is designed to be complete in itself. Further, and this illustrates the kind of improvement constantly being sought in AF weapon systems, the Titans in these later squadrons will use storable propellants and will be capable of near-instant launch direct from the hole.

With the advent of Minuteman, AF efforts toward maximum survivability at minimum unit cost come to full flower. And, with high survivability and low cost, we arrive at a favorable cost-effectiveness ratio. We are buying, as suggested earlier, the most deterrence attainable for the dollars expended. In the deployment of the Minuteman ICBM, we incorporate mobility along with hardening, dispersal, and fast reaction. We achieve, too, greater simplicity without sacrificing adequate yield, reliability, or marksman-like accuracy. Thus, with a single missile system, we close the loop on all those operational factors necessary to ensure maximum survivability at minimum cost.

The greater simplicity of Minuteman along with its lower unit cost make it the ideal ICBM to be deployed in the quantities necessary to fulfill the third major objective for deterrence—numbers.

Minuteman Tactics

The highly accurate fixed-base ICBM force attainable with Minuteman affords the U.S. an effective missile capability for programming and carrying out, if war is forced upon us, strikes against an enemy's strategic military targets. The advantage inherent in this capability, over an ability to strike soft targets, such as cities, is obvious. Cities do not fight back. Minuteman missiles can be in position, in remote hardened sites, ready to travel intercontinental ranges at a moment's notice, without loss of valuable time in getting into strategic position or moving within shooting dis-

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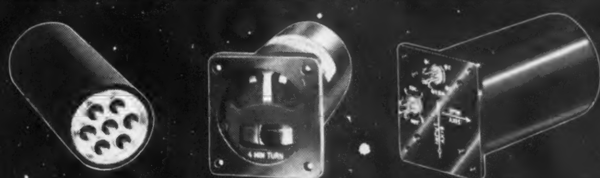

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tance of a target. In its mobile state, too—aboard special-purpose railroad cars—Minuteman will always be within ocean-spanning range of pre-determined military targets.

Actually, progress in the development of the Minuteman has exceeded the most optimistic expectations. The test program has been highly successful throughout all the progressive steps conducted to determine silo and first-stage propulsion characteristics. This has been a tricky business, for the Minuteman first stage is the largest solid-propellant rocket under development in this country. From an operational point of view, it is actually twice the size of any similar propulsion unit. In dealing with casebonded propellants, problems increase almost in direct proportion to the increases in the size of the unit.

Early in May of this year, however, the Air Force conducted the eighth in-silo test of the full-scale model Minuteman with an operational-type first stage propulsion unit. The success of these tests has made it possible to cancel the balance of 10 more proposed tests at Edwards AFB. As a double result, money has been saved and the program accelerated by several months.

The scope and the nature of U.S. defense programs testify to the versatility and flexibility of this country's growing military structure. While recognizing this, and while playing a major part in bringing this force into being, the Air Force has been concerned about enhancing the non-Communist world's deterrent posture by taking advantage of the strategic applications of space.

During the next several years, this country's land, sea, and aerospace forces will be augmented by 13 squadrons of Atlas ICBM's, 14 squadrons of Titan ICBM's, a significant number of fixed and mobile Minuteman squadrons, and a sizeable fleet of Polaris-armed nuclear submarines. These add up to an impressive deterrent package. Yet even this substantial force can be imbued with greater deterrent value by providing the U.S. with early warning, reconnaissance, and communications capabilities through the development and use of earth satellite systems.

Deterrence takes on added impact when the potential enemy knows that the U.S. is not only equipped to strike back, but is equipped as well with the means to achieve victory in war. This kind of capability represents deterrence in the broadest meaning of the word.

The Air Force has been working to increase U.S. deterrent strength by building the space systems that will provide global surveillance, rapid early warning, and worldwide communications. Many of the space projects carried out to date, using ballistic missiles as boosters, have been oriented in this direction.

If America's complexion of defense is more complex than ever before, it is simply because defense needs have never been as demanding as they are now. In looking at our country's total military program in full perspective, it would seem that very genuine steps have been taken toward meeting those demands in the most realistic manner practical. The lessons and experiences of these last six years indicate that the U.S. has no intention of being outdone, outwitted, or out-maneuvered in defending the rights of free men. ♦♦

Funding the Space Program

(CONTINUED FROM PAGE 23)

many new space programs, some of which have since been transferred to NASA.

Moreover, after NASA was formed, DOD retained most of the experienced management capability for the production of launch vehicles; all of the major launching centers from which space launchings based on military boosters could be made; and, for a time, all of its extensive research, development, test, and evaluation facilities. Subsequently, certain transfers have been made, including those of Jet Propulsion Laboratory and more recently the Development Operations Division of ABMA to give NASA the facilities and experienced people necessary to accomplish its missions.

However, although there has been a continuing clarification of roles and missions in space and a commensurate attempt to allot resources accordingly, the yearly budget cycle requires over-all program coordination to insure that unnecessary overlaps in areas such as missions, payloads and instrumentation, launch vehicles, and research programs are eliminated. The critical problem, of course, is the distribution of the elements which are always in short supply—facilities, trained technical and scientific manpower, and money. This job is accomplished by coordinating groups composed of representatives of DOD and NASA, by the Office of the Scientific Adviser to the President, and partly as the result of questions raised during program reviews held by the Bureau of the Budget staff. The situation, which is extremely complex and difficult to handle, has gradually improved, although there are still many problems for the executive branch during the consideration of a new budget.

Funding Manned Missions

In the area of missions, an example of the problems faced is the manned exploration of space. NASA was assigned this mission, and its Mercury program has been widely publicized in the press. However, when the budget is formed, four related programs have to be considered which contribute in one way or another to this mission—the X-15, Dynasoar, Mercury, and a successor to Mercury. The first and second are funded principally by DOD with heavy NASA technical support, while the third and fourth are funded by NASA with DOD support. Thus difficult research and development problems concerning many technical areas are spread out through the budgets of both agencies and all four programs.

The executive branch also faces difficult problems in funding other mission areas, such as navigation, communications, meteorology, and geodesy, because the space applications in these areas are certainly not exclusively either civil or military, and decisions have to be made as to which agency will be responsible for the specific programs. DOD is funding the navigation satellite, which, if successful, will certainly have extensive civil uses. NASA is now funding the "Echo" passive communications satellite program, while DOD is funding two varieties of active satellites and certain passive communications experiments. NASA is funding the meteorological satellite program, but here again DOD has substantial interests. Another area of joint interest in which mission assignments are being made on a case-by-case basis is the use of satellites for geodetic purposes.

There are several difficult problems from a financial management point of view with the division of space missions between agencies. A major one is that programs in the same mission area carried on by separate agencies do not compete directly with each other for dollars. Special efforts have to be made in the budget review process to assure that there is a proper balance of effort on such programs in the budget of each agency. Further problems arise in making sure that space applications being developed by one agency meet the needs of the other agency in terms of capabilities, and that successor projects are not started without proper coordination. However, these problems can be solved, and they certainly are not as

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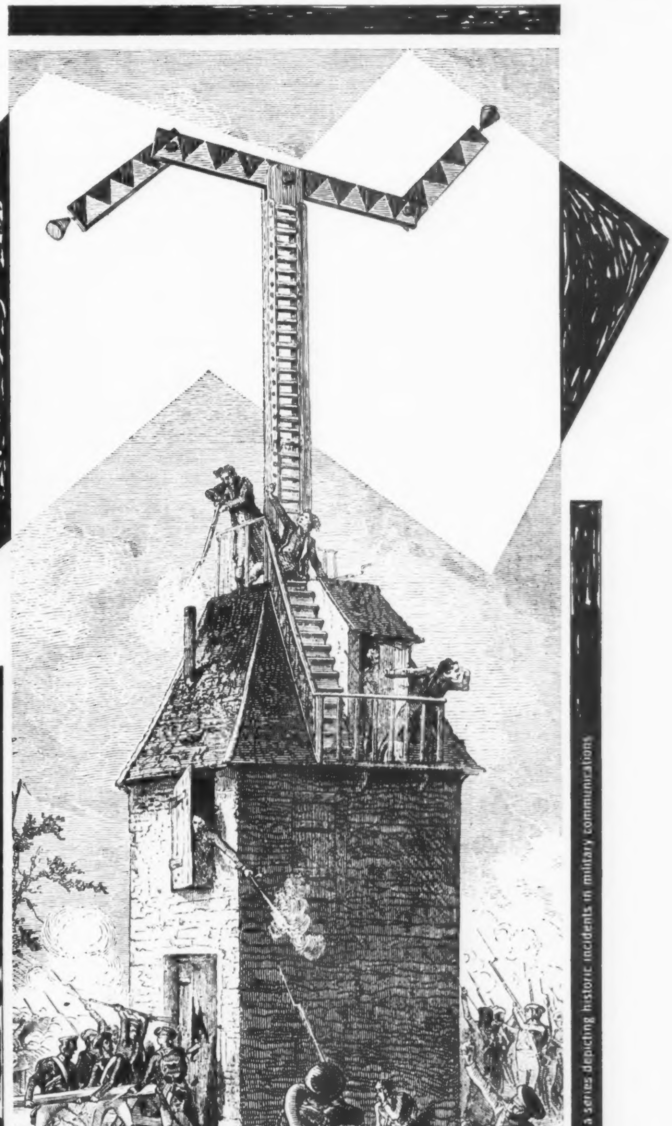

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thorny as the problems that would arise if there presently were a single space agency. This possibility, which has been given extensive consideration and so far rejected, could, among other things, mean mixed civil and defense responsibilities if the agency were civil, and a "military" tag on all of our space efforts if DOD got the total job.

In regard to spacecraft payloads, a very real problem of coordination arises for executive management. Until the ultimate sensor—man—is able to go on extended space missions, we will have to rely exclusively on complex sensors and instrumentation of many types to give us information on how well our launch vehicles and spacecraft payloads have functioned and to gather and transmit back to earth the knowledge we seek. This part of the space program is very expensive, involving many of our best minds and facilities. The problem is to coordinate payload development in diverse programs under military or civil auspices, under contract to industry, in universities, or in government laboratories. While it is true, in the case of photographic sensors, for example, that the requirements for a military reconnaissance satellite program differ from those for a civil meteorological satellite program, sensor requirements for lunar cartographic satellites as a preliminary to manned lunar landings might well be met by military sensors. In any case, all of the requirements for photographic sensors, for example, must be coordinated to achieve our objectives with the minimum cost.

Funding the Boosters

In the area of launch vehicles for satellites and space probes, there have been several problems. In the beginning, all the boosters for launch vehicles, except Vanguard, were modifications of military missiles, but the need for more efficient and larger launch vehicles was soon apparent. The government has attempted to organize this part of the space program efficiently in accordance with the common denominator in this field—weight lifting capability. In general, the objective has been to build each succeeding launch vehicle with an increasing capability of putting heavier spacecraft payload weights in orbit or on interplanetary trajectory. To accomplish this, each launch vehicle has thus far been assigned either to NASA or DOD for development, without regard to the identity of the eventual user or users.

Once the launch vehicles were assigned, however, the next problem for executive management became apparent. On the one hand, there is the need to phase the development of new launch vehicles with the availability of larger payloads to achieve an early launch date for larger and more complex missions. On the other hand, the technology in the field is rapidly moving forward, so that better boosters or payloads might be available if we could wait for them. The next decision in the launch vehicle field, then, is on how many different vehicles are needed as a family to accomplish our goals in space and whether, and at what point, successor vehicle projects should be started to incorporate the latest technology. In some cases, the new and improved vehicles, because of their increased capabilities, may become competitive with vehicles which are already well along using the older technology.

The field of basic and applied research is another problem area. This problem has two facets. First, it is difficult to know how much duplica-

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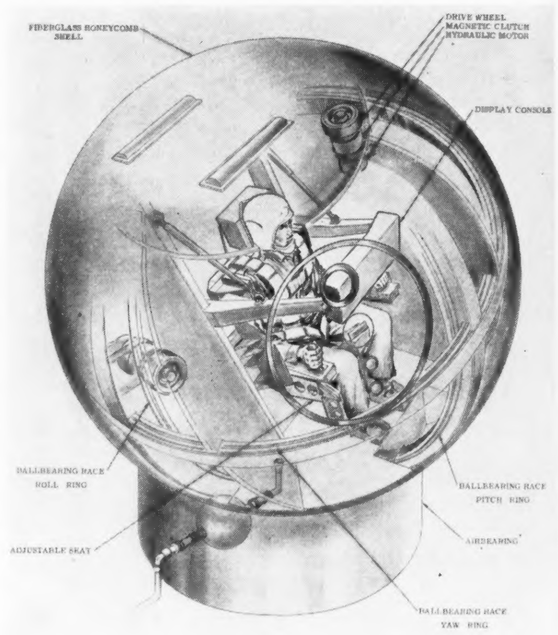
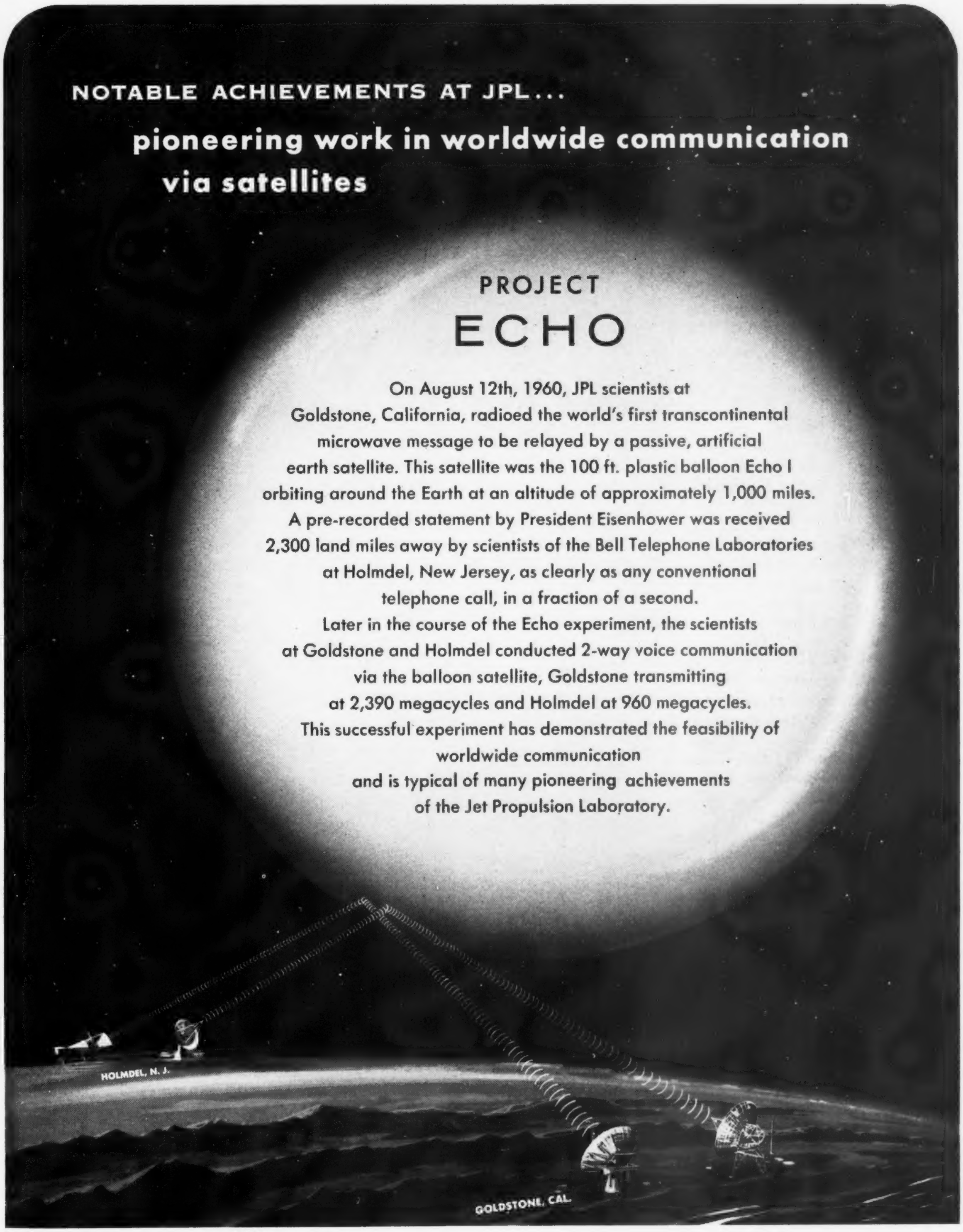


Northrop's Norair Div. has designed and is now constructing this rotational simulator for the AF School of Aviation Medicine, Aerospace Medical Center, Brooks AFB, Tex. The 4300-lb machine will allow study of an astronaut's physical and mental responses to complex rotations.



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tion or semi-duplication is necessary. Unlike the launch vehicle area where the development of two vehicles with the same capabilities would be questionable, it might be necessary to fund several parallel research efforts to crack a difficult problem. Second, there is a great variety of research underway in universities, private industry, and government institutions on space or related programs, such as aircraft or missiles, which provides scientific and technological knowledge applicable to space. Perhaps the most difficult job for executive management in this field is to get the information about the state of the art and competent advice upon which to base decisions on the level of effort to be funded in each area of research.

Major National Policy

The second major type of problem faced each year in the formulation of the space budget involves major national policy. All Americans, regardless of political affiliation, are interested in keeping our economy growing and sound. As part of this process, judgments and decisions have to be made by the President, based on the best advice he can get, concerning the amount which various government programs will receive and the total amount of the budget each year. The military space effort is part of the defense program and is considered as an important element of that program. Given specific mission objectives, the military space programs are competitive within DOD with all the other means available of accomplishing those mission objectives. The civil space programs, on the other hand, are competitive with all other government programs for dollars, and the amount of money involved is growing at such a rapid rate that it is putting more and more pressure on other important programs. The table on page 23 illustrates the budgetary impact of the space program.

In addition to all the normal pressures, the relative funding priority of the space program is affected by some very powerful Cold War psychological considerations which are taken into account when budget decisions are made. There is little doubt that the people of the U.S. are interested in the exploration of space and in the competitive position of the U.S. relative to the Russians. It is also apparent that the people of the rest of the world are using the achievements in space of the two nations for an appraisal of relative technological strengths. Because the conquest of space involves practically the entire panoply of basic sciences and technological arts, such an appraisal has some validity, if indeed both nations choose to use the exploration of space as the stage upon which to parade their achievements. On the other hand, it is unlikely that either country would be able to fund its space programs to the extent necessary to beat the other in all of the possible space "firsts."

Some people have criticized our civil programs because we have not done the same "spectacular" things as the Russians. However, our communication, meteorological, scientific-satellite, and deep-space-probe programs have all provided us with very successful "firsts" in space. With regard to recent U.S. space achievements, the President said on Aug 17, 1960:

> "The events of the past weeks have demonstrated beyond all doubt the vigor, capabilities, and leadership of the U.S. in the conquest of the frontiers of science and technology and, in particular, in the exploration and utilization of space . . .
>
> "The U.S. leads the world in the activities in the space field that promise real benefits to mankind."

NASA Administrator T. Keith Glennan emphasized these remarks on Aug. 21, 1960, by saying:

> "The genuine scientific accomplishments of our satellites surpass those of Russia."

Our civil space program is not and should not be predicated on what we think the Russian program will be in time or scope, for two reasons. First, we do not know what the Russian program will be and, second, even if we did know, we do not believe that world leadership in space can be achieved or maintained by a stop and start series of spectacular, politically timed shots. Rather, our philosophy has been (1) to seek knowledge about the universe through an extensive, well-ordered series of launchings designed to collect information on a very broad scientific and technological front; (2) to find out how space can be useful to everyone through new applications; and (3), unlike the Russians, to share the result of our space program freely with all nations.

Russian Space Shift?

Moreover, as the weight of the very substantial funding we are now placing behind the space program is felt by the Russians, we must not be unprepared if there is a shift in their emphasis on space. It is not impossible to imagine that the Russians, after having gleaned a few spectacular propaganda "firsts," will leave almost all of this very expensive field to us while moving their emphasis to other unrelated programs, perhaps more directly in keeping with their imperialistic goals. In view of the long reaction time of the democratic system of government, if the Russians do de-emphasize space, we must be sure that the fervor which was built up overnight for the space program when it resembled a race does not vanish just as quickly and leave us with a program the public does not wish to continue at a meaningful level.

The final decision which the President makes each year on the level of the space program is thus a very difficult one and will remain so. Conflicting pressures for the pursuit of varying program objectives must be balanced with the desires of 180,000,000 free Americans in deciding which direction American leadership will take. These pressures are resolved each year in the preparation of the Federal budget. Of course, no matter what decisions are made on the budget of any major program, the groups supporting that program or some other program are going to be unhappy if the nation is to live within its income.

Despite all this, we can be confident that, with the increasing pace, successes, and well-balanced nature of the American space program, accomplished within reasonable budget totals, our space accomplishments will speak eloquently for our nation and for our policy. ♦♦

Guidance and Navigation

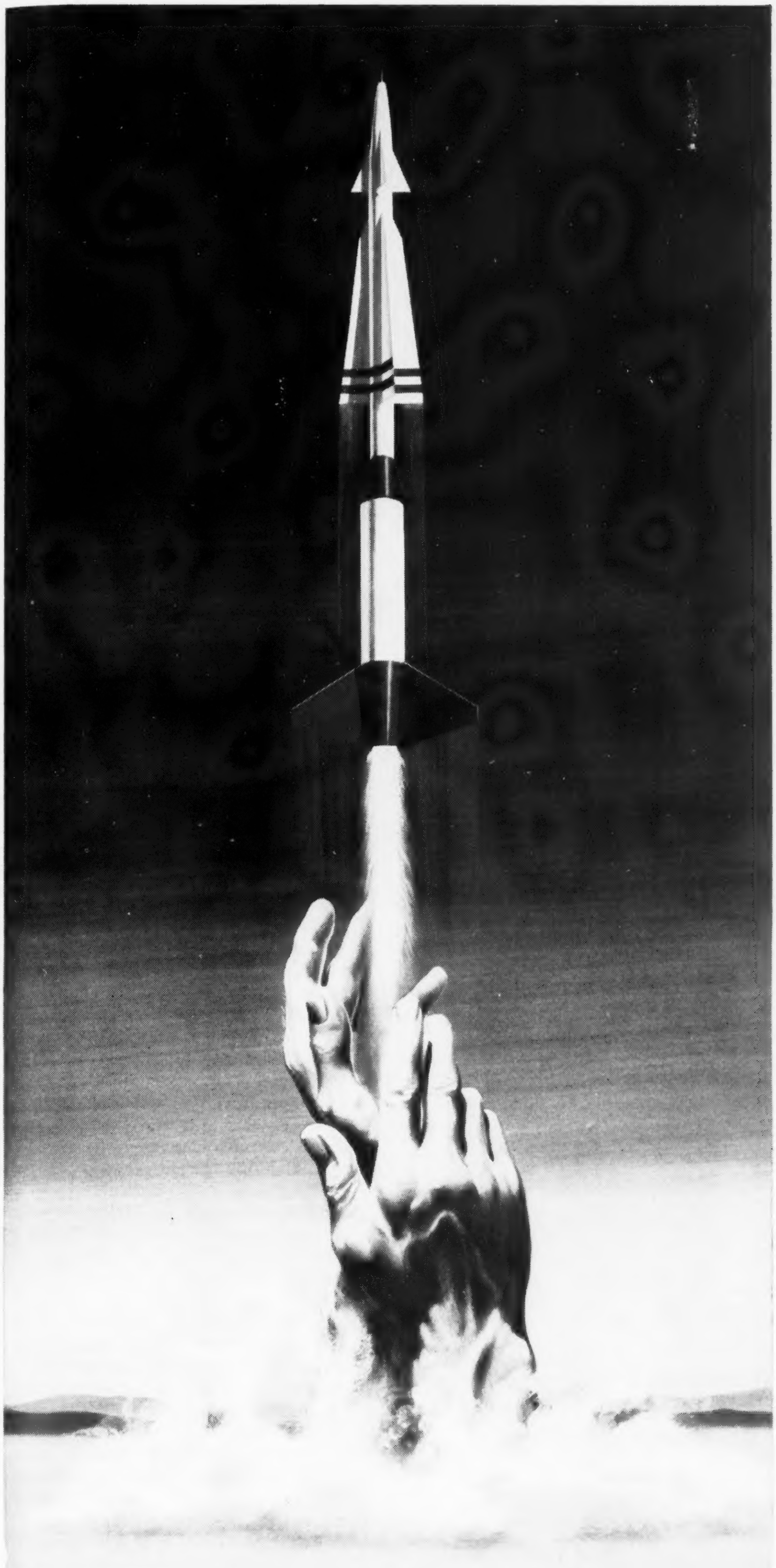
(CONTINUED FROM PAGE 34)

of basic research and development, have resulted in accomplishing what had been thought by many to be impossible.

The past year has witnessed the demonstration of inertial-guidance systems over ICBM ranges and, what is perhaps more significant, the general acceptance of the desirability of such systems.

To proponents of radio and radio-inertial systems, past and present, it is perhaps some consolation to point out that although they have lost considerable ground in ballistic-missile guidance, much has been accomplished in other areas during the same period of time. Range instrumentation, injection guidance, and satellite tracking have been developed. Many excellent developments in connection with short-range ground-to-ground, ground-to-air, and air-to-air missiles have also been successfully completed.

Today's sophisticated weapons and space programs place a continuously



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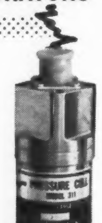

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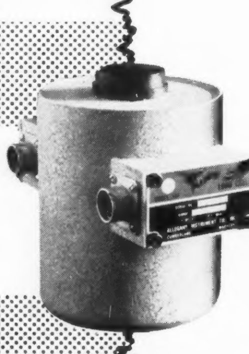

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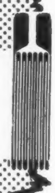

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increasing pressure on designers of guidance and navigation equipment to provide components and systems which are smaller, lighter, more accurate, and more reliable. In addition, the systems engineers find that the time allowed between go-ahead and delivery of the system to the customer has been reduced to the point where all development, design work, documentation, manufacturing, quality assurance, and systems tests must be accomplished with the utmost efficiency. To meet present-day demands, emphasis has been placed on developing components, packaging techniques, and subsystems which provide the system designer with the capability of supplying a "made-to-order" system on the shortest possible time scale.

Digital Techniques

Among the techniques which promise to allow continued improvement in guidance and navigation systems is that of utilizing digital computers in conjunction with miniaturized components and advanced packaging techniques. Although present designs demonstrate some of the advantages that can be gained, developments now under way indicate remarkable reduction in weight and size for the next generation of hardware.

The past year has seen a multitude of significant contributions by a large number of different organizations. Many new components and system developments have been announced and not a few have been successfully demonstrated. The report which follows attempts to list some items of interest which have come to the attention of the author. No claim is made for completeness, and it is recognized that many significant contributions have been omitted either through oversight or lack of information. Accordingly, the author wishes to apologize beforehand to any organizations who find that they have been omitted or inadequately mentioned.

Of considerable importance during the past year has been the successful demonstration of the guidance system of the Navy Polaris missile. This system, which utilizes a digital guidance computer, was required to operate through the difficult environment of being launched from a submerged submarine. The same operation also demonstrated the ability of the Submarine Inertial Navigation System (SINS) to perform its difficult functions of navigation and azimuth alignment. Lockheed is prime contractor for Polaris, and its guidance system was designed by MIT and is manufactured by GE, Hughes Aircraft, and

Minneapolis-Honeywell. SINS was supplied by Autonetics Division of North American.

The successful flight test of the AF Atlas missile (prime contractor Convair), with its inertial-guidance system which utilizes string-type accelerometers and a digital computer, was another important event.

On April 13, 1960, the Transit navigational satellite, which was conceived by Johns Hopkins Univ., was launched by a Thor-Able-Star, marking a new era in navigation. Transit established the feasibility of obtaining accurate position fixes by the use of Doppler signals from such satellites. The all-weather capability of this system, and the fact that no precision mechanical measurements are involved, makes this system of navigation very attractive.

The Echo satellite, launched Aug. 12, 1960, attained a highly circular orbit by means of a radio-command-guidance system developed by Bell Telephone Labs.

A significant recent achievement was the recovery from orbit of two AF Discoverer satellite capsules. The Lockheed-developed Agena vehicle contained an attitude-control system using an infrared horizon scanner and an inertial-reference system. Re-entry was close to the nominal point and the last capsule was actually snared in mid-air by an airplane as the capsule descended by parachute.

The Centaur guidance system, which NASA has announced is to be capable of placing a payload on the moon or establishing precision satellite orbits, including 24-hr orbits, employs a miniature Minneapolis-Honeywell gimbal system and a digital computer by Librascope. This system recently completed acceptance tests and has been delivered to Convair, Centaur prime contractor.

Autonetics Div. of NAA has rocket-sled tested a prototype guidance system for the Minuteman missile. A key requirement for this system is that it remain operable for long periods of time in hardened underground silos without human maintenance. Long life and high reliability are therefore a must for the system. It has also been announced that the Hound Dog missile, which utilizes an Autonetics' inertial-guidance system, was recently carried by a B-52G to the North Pole, where extensive tests were performed. Upon returning from the 10,800-mi nonstop flight, one of the two missiles being carried was successfully fired over the Atlantic Missile Range.

The recently tested X-15 makes use of an inertial flight-data system developed and built by Sperry Gyroscope Co. The platform has special

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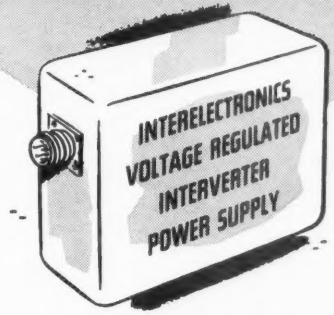

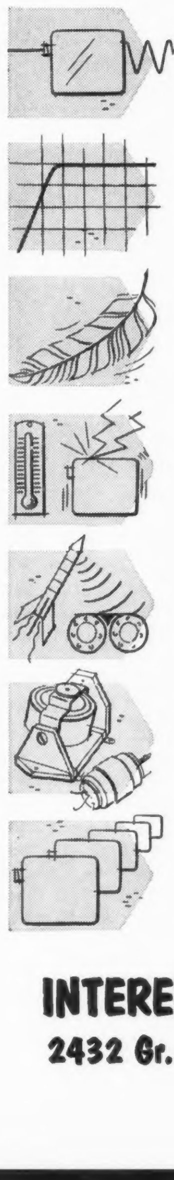

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design features to enhance the reliability.

Eclipse Pioneer Div. of Bendix has begun delivery of the ABMA-designed Pershing inertial-guidance systems to the Army. They are presently undergoing laboratory evaluation prior to being flight tested. An interesting development recently completed at NASA's Marshall Space Flight Center is a Satellite Motion Simulator. This device consists of a large platform which is mounted on a spherical air bearing and which has compensating devices to correct for torques caused by temperature, anisoelasticity, and out-of-roundness of the sphere, which incidentally has a tolerance of 0.00005 in. Using this simulator, attitude control systems such as those based on small spinning wheels can be adequately tested.

One of the most interesting component developments which has come to the author's attention during the past year is a miniature gyroscope which utilizes a gas-spin bearing and is constructed largely of a ceramic material. In this device, Minneapolis-Honeywell, the developer, has applied a very powerful approach to the solution of several problems which have plagued gyro performance and accuracy. By utilizing the gas-spin bearing in conjunction with a hard ceramic material, the life of the spin-axis bearing becomes virtually unlimited. In addition, it is claimed that the isoelasticity of the bearing can be accurately set. The gas-spin-axis bearing requires that the critical ceramic parts be ground to tolerances on the order of five millionths of an inch, a very difficult problem but one which the developer states has been solved through the use of specially developed techniques. The new gyro is similar in size to the well-known MIG and, according to the manufacturer, will represent a tenfold increase in accuracy.

Other important developments being pursued in the gyro field have to do with electrostatic and electromagnetic suspension. Such support techniques are expected to provide far greater accuracy than can be obtained from presently used techniques. Minneapolis-Honeywell has released some details of its electrostatic gyro development and claims that feasibility of a super-accurate gyro has been proven. GE has been working on an electromagnetically suspended cryogenic gyro about which some information has appeared in the literature.

Bell Aerospace Corp. has announced development of a precision two-degree-of-freedom gyro designated the Brig II, which uses a unique gyro-housing rotation mode of operation to eliminate low-frequency drift effects. Bell has also developed a precise digital velocity meter based on its Model III B accelerometer. Instruments having digital output are becoming more in demand due to the trend toward digital guidance computers.

A number of concerns have announced the availability of miniature stabilized platforms for use in inertial-guidance systems. Norden, in an interesting brochure, describes its four-gimbal platform having gyros and accelerometers of its own design and manufacture and having a total weight of less than 20 lb. Litton Industries, Minneapolis-Honeywell, GE, Kearfott, and others have also developed precision-guidance platforms.

Kearfott has under way several interesting developments. "Gytar," a portable gyro-azimuth-reference device, is claimed to be accurate to within 10 sec of arc and will have a ready time of less than 15 min. Among other developments, Kearfott has announced that development is proceeding on a miniature solid-state sun tracker for satellite application which has no moving parts and is accurate to 0.1 deg.

Of interest as a reference instrument for short-range missiles, drones, and target vehicles is a new gyro, the "Genie," recently announced by Lear, which utilizes a hot-gas drive, and is said to have high reliability due to its extreme simplicity.

It is, of course, impossible to list all the recent contributions. However, the above mentioned items demonstrate the rapidity with which progress is being made in the field of guidance and navigation. Although much has been accomplished, there is literally a universe to be conquered. Let's get on with the job! ♦♦

Instrumentation and Control

(CONTINUED FROM PAGE 37)

resulted in numerous methods and techniques, but a very promising one for engine use is now on the market. This particular unit has simultaneous mass and volumetric rate output signals. It is based on the standard turbine type meter and represents little increase in complexity of operation. It is about 50 per cent longer than the volumetric but has the same diameter for a given flow rate range. The manufacturer and users who have run evaluations have found good operation to −300 and 850 F in both liquids and gases. The repeatability has been demonstrated as $^1/_4$ per cent of reading.

With the increase in combustion temperature and pressure, the heat-transfer problems in cooled, heat sink, and ablative nozzles have increased in difficulty. A transducer capable of measuring steady-state local heat flux has been designed and a prototype employed successfully. This unit has an active element 0.2 in. in diam in an over-all OD of 0.5 in. The time constant is about 200 millisec. The unit has a cooling capacity of 20 Btu/sq in/sec to withstand the most rigorous heat flux conditions which might be encountered in a rocket chamber or nozzle. After calibration, the unit, installed in a regeneratively cooled motor, showed excellent agreement with heat flux data derived from standard bulk coolant temperature measurements.

New Total-Radiometer

To aid more detailed studies of the rocket combustion process, a total radiometer has been developed which can operate within less than a foot of a combustor. Looking through a sapphire window, this instrument, which includes a lens, chopper, and drive motor, also has a detector which has a time constant of the order of 1 millisec and has been designed for stacking of multiple units $1^1/_2$ in. center to center along the motor wall. Even acoustic noise as high as 120 db has an insignificant effect on signals detected. This was accomplished by the use of solid-state circuitry for preamplifier and demodulator reference circuits.

The battle against electrical noise in test-facility measurement systems showed significant success through the commercial availability of isolated sensing elements and lower capacity, low-noise multiconductor cable. An isolated accelerometer now allows a single complete instrumentation channel to be kept above ground. This has resulted in a 20 db improvement in signal-to-noise ratio with the attendant advantages of greater fidelity and sensitivity.

Multiconductor cable is now available with a low capacitance between conductors and between conductors and shield. This capacitance is less than 20 micro micro farads per ft, which approaches that of coaxial cable. It enables measurements of changes in pressure, strain, and vibration which

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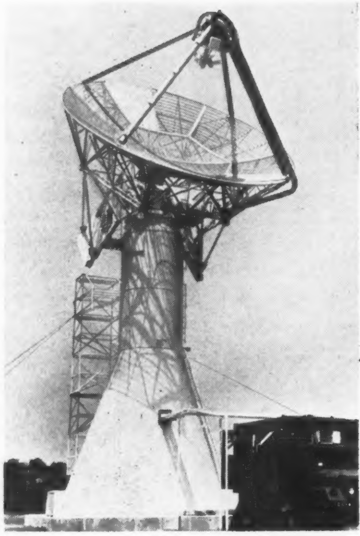

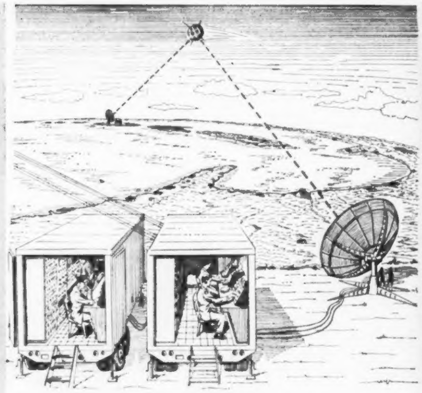

Courier I—Toward Military Global Communications

Launching of the ARPA-shepherded Courier I satellite Oct. 4 opens the way for global microwave communications for the military services. Shown at the right being assembled, the solar-cell-covered satellite, developed by the Philco Western Development Laboratories, extends the "delayed repeater" concept demonstrated with Atlas-Score in 1958. Courier I can also be used for real-time communication between ground stations mutually having it in view. A van system developed by ITT and the Army Signal Corps can send and receive 340,000 words in 5 minutes each time the satellite comes in view of a station, as indicated by the diagram. Radiation Inc. designed and built two special tracking antennas, like the one shown at the left, to provide the high gain necessary for a reliable two-way link, ground to satellite, during a specific interval of orbit. The antennas are at the Army's Space Communication Center near Ponce, Puerto Rico, and at its Astro-observation Center, Fort Monmouth, N.J.

take place up to 10,000 cps using land lines as long as 3000 ft.

The need for primary power sources for use in satellites has resulted in a great deal of research in high-temperature liquid-metal heat-transfer loops. This latter has in turn generated the need for sensing elements to measure temperature, pressure, liquid level, flow rate, and quality of the fluids. One instrument which has been developed and used successfully in this work is a liquid-metal level detector. The sensor provides a continuous analog signal output which is completely independent of temperature. It is located external to the liquid metal reservoir as well as any flow lines. To date, it has been successfully applied to high-temperature sodium and potassium thermal loops for both measurement and control.

The most significant advance in recording has been the order-of-magnitude improvement in the drift and accuracy characteristics of magnetic-tape recorders. As a case in point, by using new recorders, land-line strain measurements on rocket-engine components have been improved from a figure of 5.7 per cent full-scale to an estimated error of 2.8 per cent. This improvement has resulted from the engineering of small gap heads with low scattering coefficients, improved tape, and improved head shape which aids head-to-tape spacing.

Another advance has been in the successful recording of pressure amplitude variations, as sensed by a pressure pickup, as variable-density film records. This is a distinct aid in the correlation of combustion light and pressure. The system has been designed for a 35-mm streak camera, the lens of which looks through a quartz window in the wall of the combustion chamber. A lamp located within the camera normally used for timing marks is modulated by the signal from the pressure sensor. The electronic circuit has a threshold control for recording signals in excess of a predetermined amplitude only.

A significant advance in calibration of high-capacity flowmeters used for rocket-engine testing was made with accuracy of $^1/_4$ percent at the 95-per cent confidence level reported by one engine manufacturer. Here, a certified flask has been used in calibration of liquid-level gauges installed in test-stand tanks. The flowmeters are then calibrated against the level gauges during engine tests.

Flowmeter Calibration

Another engine manufacturer has designed and installed a high-capacity cryogenic-fluid-flow bench on which flowmeters are calibrated prior to test-stand use. The accuracy demonstrated by this bench is 0.1 per cent at the 95-per cent confidence level using liquid oxygen and liquid nitrogen.

A general improvement in analog-to-digital conversion of data has resulted from the general availability of equipment capable of conversion rates in excess of 10,000 samples per sec and 0.5-per cent accuracy. A resulting increase in bandwidth of single channel as well as multiplexed data is an additional benefit.

Vibration Studies

Successful simulation of three degrees of freedom simultaneously in vibration with one driver unit was accomplished. Using vector methods, two electronic amplifiers were subjected to random loading with a high degree of success.

The interest in use of boron fuels and the subsequent hazards in testing has resulted in the development of a borane detector which measures continuously the concentration in air of any of the volatile boranes.

The instrument contains (1) an electrochemical detection cell, (2) a DC amplifier for amplifying the signal from the detection cell, (3) an air-sampling pump, (4) nickel-cadmium batteries, (5) a built-in line-operated battery charger, and (6) a filter for minimizing interference from hydrazine. It is a self-contained unit which can be carried into the field.

The sensitivity of the detector under favorable conditions (e.g., operation in the laboratory) is approximately 0.01 ppm of pentaborane. In typical field use the sensitivity is approxi-

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mately 0.1 ppm. The response time of the instrument is approximately 1 min, and hysteresis does not occur except under severe conditions.

The detection cell consists of a polarized platinum screen electrode, a liquid electrolyte supported on gauze, and a silver-silver chloride reference electrode. It is connected to a reference cell in such a way as to minimize drift from various sources.

If care is taken to keep the electrodes of the detection and reference cells properly conditioned, the instrument is reliable and free from trouble. If the electrodes are not conditioned regularly, response of the instrument is erratic.

An interesting photosensitive device for detecting the position of visible to infrared radiation in two axes has recently been developed. When used with an appropriate lens system, output voltages are produced at the x and y terminals which are proportional to the coordinate positions of the optically concentrated radiation on the face of the detector.

Ultra-sensitive strain gauges based on the semiconductor principle are now available. The sensitivity of these strain gauges is approximately two orders of magnitude higher than the conventional metal type. The low impedance results in a very attractive signal to noise ratio. Their high sensitivity permits instrumentation in applications which heretofore have been impractical.

The value of these achievements to the rocket and space industry may be summarized as follows:

1. Greater accuracy and stability will allow improved control of programming of flights and probably fewer instances of failure.
2. Advances in techniques for acquisition and processing of data from dynamic phenomena will allow refined analysis of engine performance so necessary when seeking the ultimate in performance, controlled responsibility of engine manufacture, and predictable performance.
3. Reduction in time necessary to process test data, and the elimination of personal error in data handling, will accrue from using atomic data acquisition and processing system.

Acknowledgment

I wish to thank those members of the ARS Instrumentation and Control Committee and my associates at Rocketdyne who have supplied most of the information contained herein.

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Structures and Materials

(CONTINUED FROM PAGE 47)

ings. Their continued development offers an interesting potential of substantial significance.

A major development during the past year involves the availability of pyrolytic graphite as a high-strength, ultrahigh-temperature material in various sizes and shapes. The material could have a major impact on both short- and long-time thermal-protection-system designs both from the standpoint of feasibility and efficiency. The use of such materials for major structural components, however, will involve special design techniques to cope with the many problems associated with brittle materials. There is some research effort in this area at present, and a more significant effort would seem to be warranted.

The development of refractory materials for hot structures as well as radiation-shielded structures constitutes a major portion of our national research and development efforts in airframe materials. Important progress has been made in the development of columbium- and vanadium-base alloys as well in tungsten- and molybdenum-base alloys. Concurrent development of coatings for the refractory metals is proceeding apace with the alloys..

An interesting analysis of the structural behavior of refractory materials revealed that metallics and nonmetallics are quite similar in this respect: Significant reductions in strength occur at about 0.6 of the absolute melting point. Thus, radical

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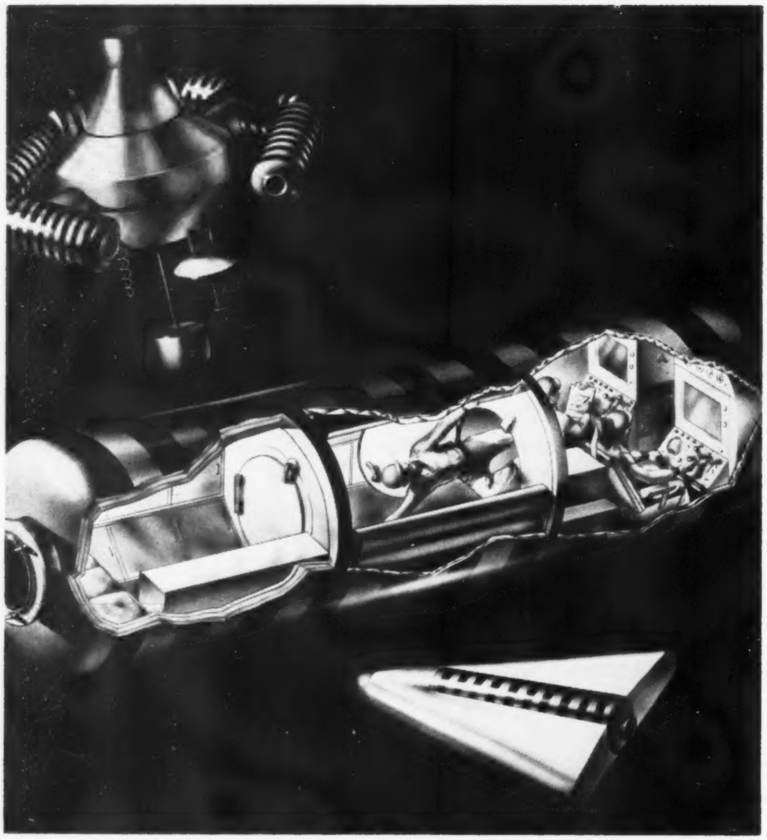
Double-Wall Space Structure



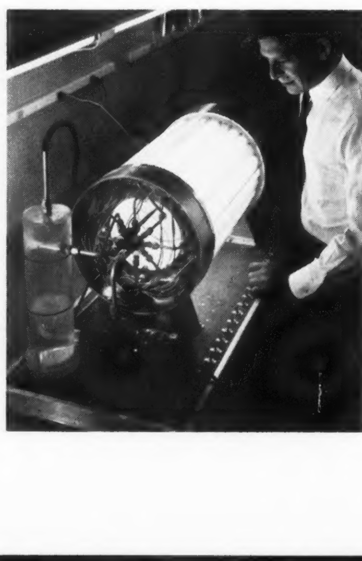
Possible applications of Aeronutronic double-wall space vehicle structure are shown in this artist's drawing. Cutaway in center shows compartmentation, with space station and winged re-entry configurations at top and below.

Aeronutronic Div. of Ford Motor Co. has designed a three-man orbiting space vehicle utilizing a stiffened cylindrical shell of double-walled construction as part of an 18-month guideline study of advanced AF vehicles carried out for WADD. Skins of the structure could act as shields against cosmic and solar radiation and meteoritic impacts, while gases required to maintain a habitable environment could be circulated within the walls.

The design is for a structure approximately 15 ft in length, with a 7-ft inside diam, which incorporates a highly secure area completely shielded from cosmic radiation. Provision is made for a compartmented interior to allow a section penetrated by a meteorite to be sealed off.

Oxygen Regenerator For Space Vehicles

Michael Del Duca of the TRW Tapco Group's advanced engineering staff views the company's developmental oxygen-regeneration system operating in the laboratory. Its fluorescent tubes, irradiating an aqueous algae culture, would be replaced by a solar source of light in a space vehicle. The vertical column at the left separates oxygen from the algae culture.



departures in the structural behavior of non-metallic refractories from that associated with metals are not to be expected.

Shell Structures

The acute importance of high strength/weight-ratio shell structures in missile and space-vehicle boosters has resulted in renewed research and development efforts in this field. Results become available from research on the instability of pressure-stabilized shells under compression and bending, and other research programs into the instability behavior of stiffened and unstiffened shells got well under way during the past year. Because of the greater relative importance of tension structures in solid-propellant engines, it is notable that progress was evident this year in the development of high strength/weight-ratio pressure vessels.

After the initial disappointments with high-strength-steel pressure vessels, sufficient progress has been made in recognition of the importance of careful design and fabrication as well as screening of materials to permit the successful construction of steel pressure vessels above the 200,000-psi strength level. Particularly dramatic was the successful fabrication of all-beta-titanium alloy 10-in.-diam welded pressure vessels that consistently resisted hoop stresses over 200,000 psi before bursting.

Although developments in the pressure-vessel field have been most encouraging, research directed toward even higher strength levels is continuing. Considerable progress has been made in understanding the interrelations among pressure-vessel and material strengths as affected by ductility and stress concentrations. Further development of high-strength materials of improved ductility as well as more-advanced fabrication concepts will ultimately lead to significant improvements in this area.

Concurrent with these developments with homogeneous materials are the significant results beginning to come to the fore in the field of filamentary materials. Significant progress has been reported during the past year in the development of inherently high-strength glass, beryllium, steel, titanium, and refractory wire filaments. Basic understanding of the use of such filaments in combination with a ductile matrix to form shell structures is progressing at an encouraging rate as a result of an expanding research effort. Finally, important results have been reported from research on optimum configurations for shells of filamentary materials.

Because of the large size of solid-propellant rockets, research on the

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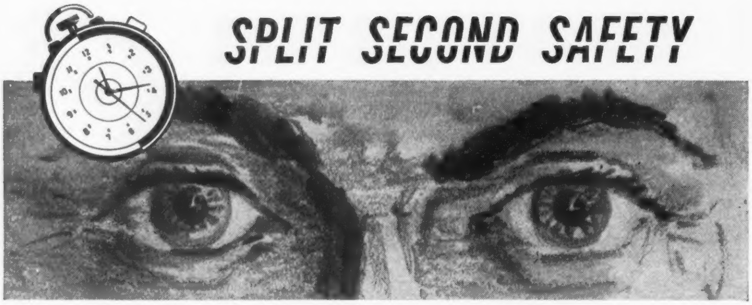

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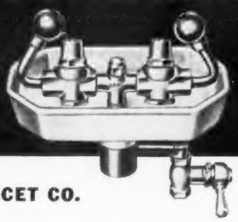

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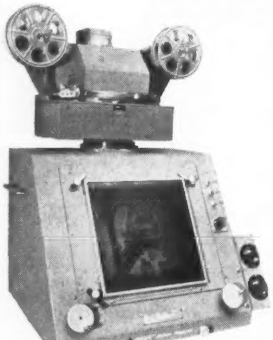

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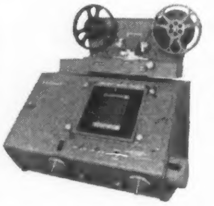

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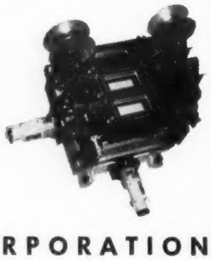

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structural integrity of the propellant grain has assumed considerable importance within the past year or two. As a consequence, the behavior of viscoelastic solids has been under intense investigation. It is anticipated that the coming year will see a rapid expansion of research effort in this important problem area.

Manned Space-Vehicle Concepts

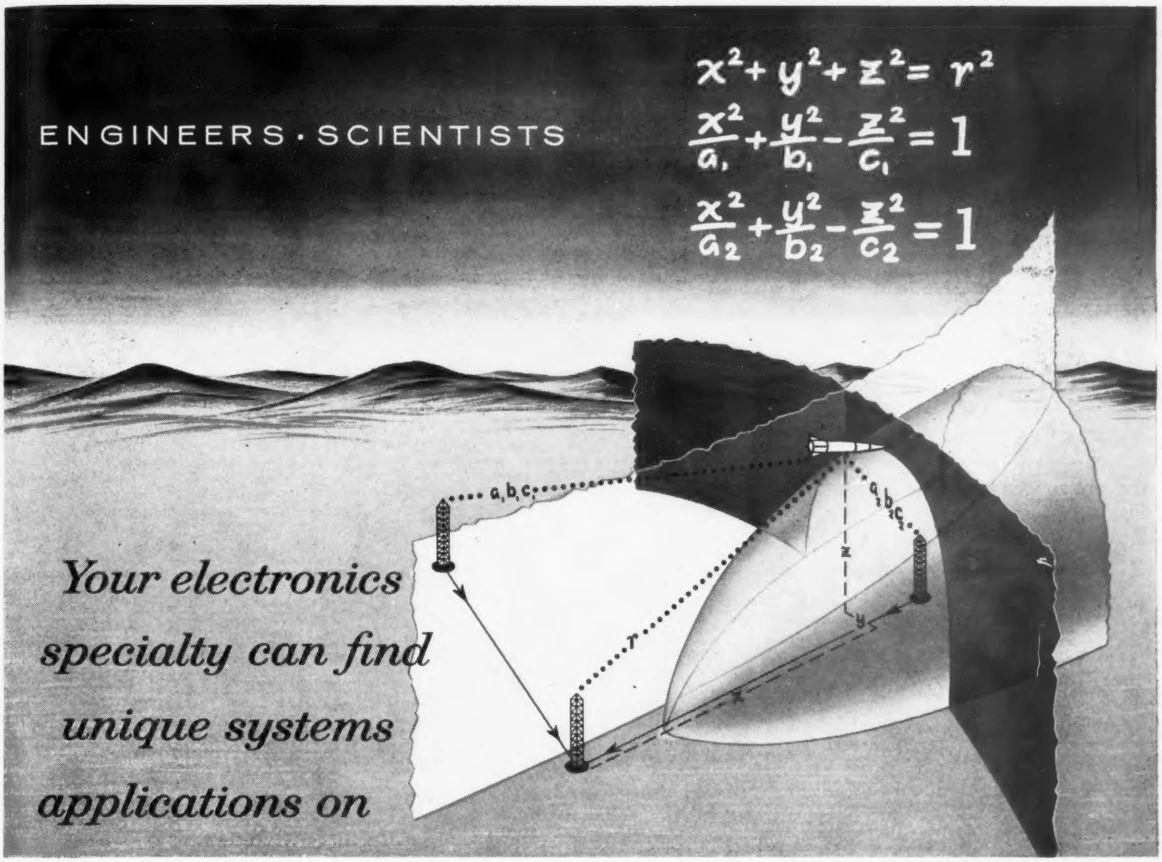
Although current satellites and space probes are relatively free of major structural and material problems, active consideration of manned space vehicles has raised questions concerning the space environment and its long-time effect upon structures and materials. At the same time, the acute need for minimum-weight structures has led to radical vehicle configuration proposals as well as highly imaginative use of materials in erectable space structures. A particularly noteworthy achievement during the past year in this regard is the success of the Echo satellite.

In the environmental area, the determination that the solar-flare radiation hazard may be of primary importance for manned space-vehicle structures has far-reaching implications. Current estimates of the severity of this hazard indicate that space flight beyond the proximity of the earth may not be possible unless new shielding techniques are developed. Recognition of this problem has already resulted in the interesting proposal of concentrated shielding "storm cellars."

Another potentially significant item during the past year was the development of high-strength lead alloy for shield structures. Strengthened by dispersion hardening, this alloy has over five times the strength of commercial wrought lead and one thousand times the creep strength at 300 F.

A rather incompletely understood environmental factor is concerned with the influence of meteoroid impact upon space-vehicle design. Although progress in assessing the meteoroid environment in space has been disappointing, the considerable effort in hypervelocity-impact research is beginning to pay dividends. Particularly noteworthy are experimental results obtained during the past year that indicate the effectiveness of the Whipple meteoroid-bumper concept (see photo on page 47). Much remains to be accomplished, however, particularly in the difficult area of equipment development for hypervelocity testing.

The important design concepts and engineering criteria underlying long-lifetime space vehicles of significant size have only recently achieved a



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▲ Basic MISTRAM system features radio receiving stations in "L"-shaped configuration. Signals from missile transponder are measured on CW carrier for computer calculation of phase differences. These yield missile position, velocity and trajectory data through spatial intersection of a sphere (range from central receiving station) and hyperboloids of revolution (range differences from remote receiving stations).

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Defense Systems Department is Prime Contractor for MISTRAM.

DSD is now developing a basic system unit which can be multiplied many times over and integrated into a vastly extended MISTRAM system, using G-E's 'building block' approach. Ultimately this would provide hemispheric coverage for missile trajectory measurement.

first-round level of appreciation. It is particularly notable, however, that progress in assessing the structural significance of meteoroid and radiation environment in space has been rather disappointing, particularly in view of the profound influences these factors will have on fundamental design concepts. These environmental factors can only be evaluated in space, and consequently satellite and space-probe experiments devoted specifically to meteoroid and radiation effects are urgently needed by those involved in structural design of space vehicles.

What may be lacking in our understanding of the space environment is compensated by some of the intriguing structures-materials concepts that are now emerging for coping with the special requirements of space vehicles. The enormous potentialities of tailoring materials to structural requirements offer wide freedom in design, seemingly to be limited only by lack of imagination. The success of ablative materials in severe thermal environments and the potential of filamentary materials and inflatable structures clearly portend a new era of significant gains in structures-materials design.

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♦♦

Solid Rockets

(CONTINUED FROM PAGE 45)

pellants actually required in the missile tanks to perform the mission. Development cost of the propulsion system, the ground-support equipment necessary to supply the missile and check it out, the number of personnel required, and the cost of their housing and supply—all these, added to the unit cost of the hardware for the rocket engine and the tankage for each missile, constitute the major items entering into the cost equation.

When all of these factors are considered, the real advantages of solids become apparent. The result is that every major weapon system which has been started since 1957 has been based on the use of solid-propellant rocket motors.

The Air Force, for example, is concentrating heavily on development of the three-stage, all-solid-propellant Minuteman as the missile which will supersede the liquid-propellant Atlas and Titan missiles in the ICBM category. The Skybolt is a two-stage solid-propellant missile of intermediate range ballistic capability which is to be air-launched from aircraft such as the B-52 to provide a singularly invulnerable deterrent capability. Research and development contracts have been let to two different companies for the purpose of developing solid-propellant rocket motors which will deliver total impulse up to 100 million lb-sec. Emphasis is on establishing a design which will cost the least in use.

The Army is developing the two-stage, solid-propellant Pershing to provide a much needed tactical ballistic missile in its range capability. The Mauler, Redeye, and Shillelagh are three important field weapons which are in development. The Navy, of course, is well along the way with development of the important Polaris missile. They are all powered by solid-propellant rocket motors.

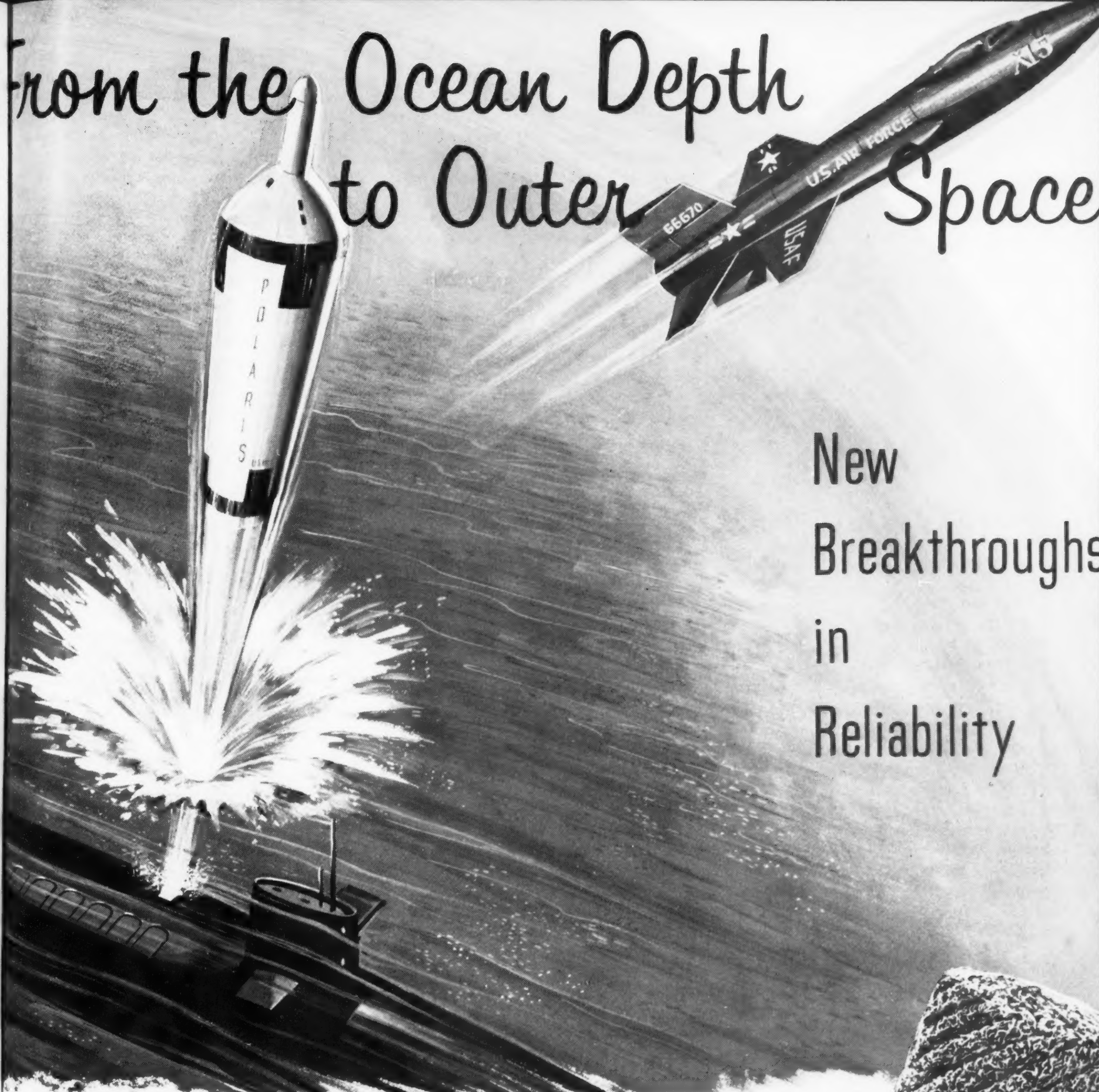
Astonishing success has been achieved to date in the development testing which has been performed on these solid-propellant missiles. Minuteman was tested successfully eight straight times in launchings from simulated or prototype silos and is about to be flight-tested under full first-stage power. Pershing has been flight-tested seven times—seven successes. Polaris has been flight-tested 73 times, including 10 launchings from beneath the surface of the sea. It is difficult to evaluate the performance record of just one component of a complete missile because of the effects of interaction of components and because of a need to classify degree of success. Taking all things into consideration, the prime contractor, Lockheed, has stated that for those missile tests for which the data have been reduced, there have been no failures attributable to the propulsion system. In other words, when the ignition signal has gotten to the propulsion system, the motors have in all cases ignited and functioned properly.

Reliability Record

This is indeed a remarkable record of reliability for the initial flight testing of new missile systems. Equally impressive is the facility with which these tests were conducted. When a missile is ready for firing, a countdown is conducted during which a final check is made of every component which can conceivably fail and disrupt the test. During initial flight-testing of missiles powered by liquid-propellant rocket engines, countdowns sometimes take several days because of the holds which are imposed when some component is found to be inoperative or faulty. These delays, of course, usually mean slipped schedules and time lost to the program. When the Minuteman silo-launch tests were conducted at Edwards AFB, the countdowns took about 2 hr, most of which was spent in checking ground instrumentation and missile tethering equipment. Firing schedules which had been established for over a year were met to the day. The point to be made here is that because all of the precise mixing of ingredients for solid propellants is done under ideal conditions at a ground-based chemical plant and because every phase of the operation is checked and double-checked during the process, there is remarkably little which must be rechecked when the motor is delivered to the launch site. The simplicity of the handling requirements make the final product an extremely useful article.

The National Aeronautics and Space Administration, as a whole, has not as yet been in a position to take full advantage of the desirable characteristics of solid rockets as have the Armed Services.

The only major liquid-engine developments now under way in the U.S. are sponsored by NASA for use in vehicles for scientific exploration of space. These engines are the 1,500,000-lb-thrust liquid oxygen/RP-1 cluster which is slated for use as the first stage of the Saturn vehicle; the



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200,000-lb-thrust liquid oxygen/liquid hydrogen engine for upper stages of Saturn; and the 1,500,000-lb-thrust, single-chamber liquid oxygen/RP-1 engine (F-1) for the Nova concept. Current work on liquid engines for the military is limited to modifications of existing designs to upgrade their performance or to permit use of non-cryogenic propellants, e.g., modification of the Titan engines for using the storable liquids, UDMH-hydrazine fuel and nitrogen tetroxide oxidizer.

NASA Activities

The Solid Rocket Office in NASA has been quite active in encouraging the further development and use of solid motors and has accomplished much with its remarkably small budget, less than $2 million for Fiscal 1961. One of the most important studies being sponsored by this group is a three-contractor survey and analysis to determine the most nearly optimum size and design of solid boosters to launch sizable payloads into orbit and deep space. System costs of the vehicles, particularly the cost of the solid booster and its required ground-support equipment, will be determined and compared with the costs of a liquid-propellant system designed to perform the same missions. It is anticipated that the studies will show that a considerable saving in U.S. taxpayer dollars can be made if solid-propellant boosters are used in future space vehicles.

Experience of the NASA Langley group with on-the-shelf solid-propellant motors used in stacks for sounding rocket and orbital-probe applications has been gratifying. For example, the Scout vehicle was developed to have the capability of placing a 150-lb payload in orbit 300 mi above the earth. Low cost was the byword of the project. Rocket motors were selected which were already developed and which were immediately available. The Scout consists of the following motors: First stage, Algol (Aerojet Senior); second stage, Castor (Thiokol XM-33); third stage, Antares (ABL X-254); and fourth stage, Altair (ABL X-248). The first vehicle was assembled and successfully fired on July 1, 1960. The accomplishment was all the more remarkable because the entire project was systems-managed and the vehicle was assembled and launched by NASA personnel without previous large-scale missile experience. This is a real tribute both to the astuteness of the personnel involved and to the fundamental characteristics of the rocket motors which lend themselves to an accomplishment of this sort.

A total of eight Scout vehicles are to be launched under a budget of $15 million, which includes the design, fabrication, and installation of the launching facility. A similar program using a rocket designed to carry only a 50-lb payload and powered by liquid-propellant engines cost more than 10 times as much less than three years ago.

Similarly good results have been achieved with other solid motor stacks. The NASA Argo D-8 missile was put together and successfully fired on the first attempt. This missile was designed to carry 130 lb of scientific payload to an altitude of 1200 mi. It consists of the following rocket motors: First stage, Sergeant plus two Recruits (Thiokol); second stage, Lance (Grand Central Rocket); third stage, Lance (Grand Central Rocket); and fourth stage, Altair (ABL X-248).

There are many other examples which could be cited of the reliability, flexibility, and general usefulness of currently available solid-propellant rocket motors. The NASA Langley group, for example, has made numerous firings with stacks of five and six solid rockets arranged in tandem. These demonstrations are made almost routinely and attract little or no publicity. Such is the state of development of solid-propellant motors.

A Summing Up

The programs just mentioned have accounted for a major share of the total progress made in the solid-rocket field during the past year. A summary of the principal accomplishments of the year would include:

1. The Polaris missile has progressed far along the way toward operational status. Numerous successful full-range missiles have been fired from submerged submarines under simulated operational conditions.

2. The Minuteman has completed a program of silo-launch tests so successfully that the scheduled series of tests was cut in half, thereby saving several million dollars. Successful static firings have been demonstrated with flight versions of motors for all three stages. Essentially all of original motor design specifications have been demonstrated.

3. Numerous flight tests of the Nike-Zeus missile have been accomplished successfully.

4. The Pershing missile has been successful in all of its initial flight tests.

5. The first NASA Scout has been successfully launched and has demonstrated its design capability.

6. Prototype models of motors which are designed to have propellant mass fractions (the ratio of useful propellant to motor gross weight) of 0.95 or better have been successfully tested.

7. Specific impulse values in excess of 250 sec (standard sea level conditions, p_c = 1000 psi, 15 deg nozzle half-angle) have been demonstrated.

8. Hybrid rocket engines employing solid fuel and liquid oxidizer have successfully demonstrated full-range thrust magnitude control (from 0 to 100 per cent) through numerous cycles. Very smooth combustion characteristics were reported at all levels of thrust.

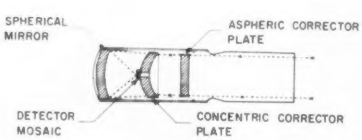
The following events of the past year are considered to have very important implications for the future of solid rocketry:

1. The Air Force contracted for the

Telescope Eye on the Sky

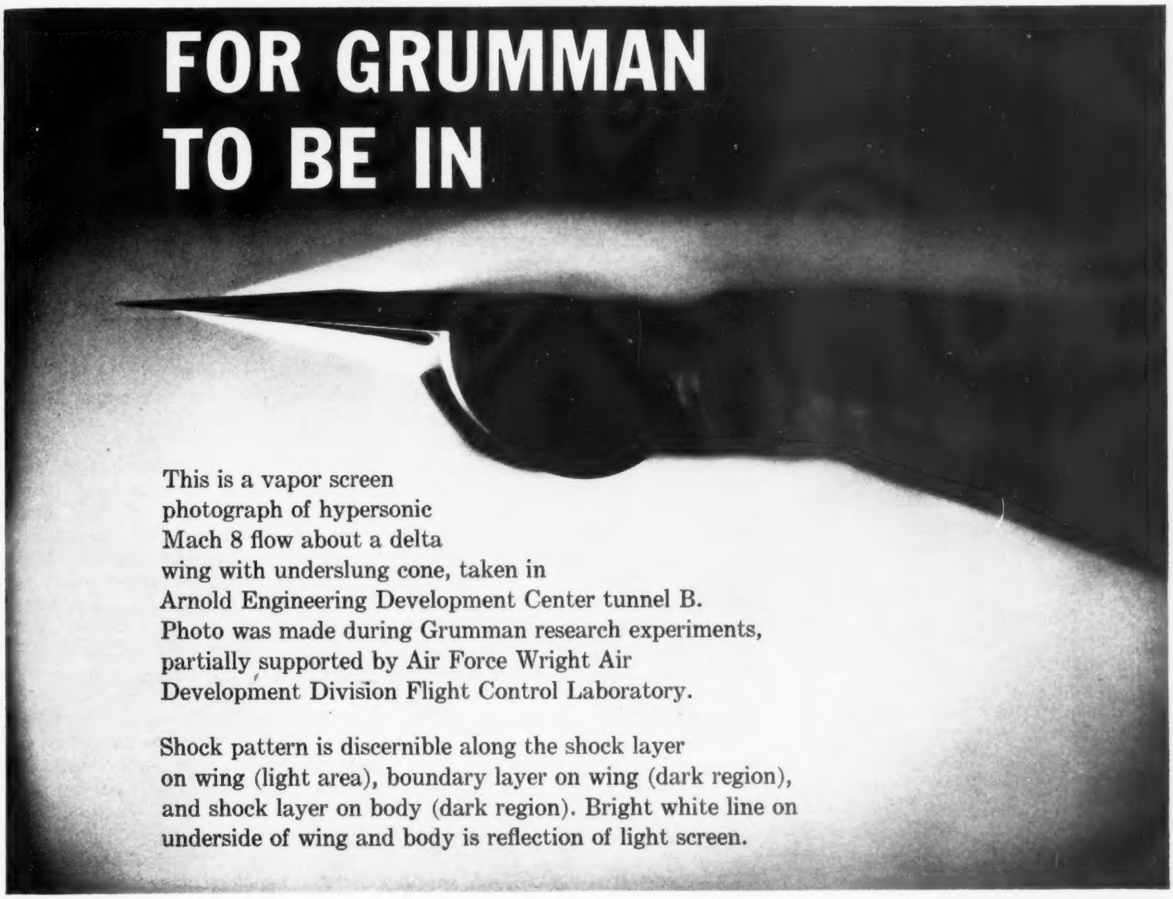
An all-sky satellite surveillance system utilizing high-altitude balloon-borne optical instrumentation is under development for the AF Geophysical Research Directorate by Electro-Optical Systems, Inc. Heart of the system is a 20-in. modified Bouwers telescope suspended from a 200-ft-diam balloon at altitudes of about 20 mi. At this height, solar radiation reflected from unannounced satellites can be detected over ranges of several hundred miles. Vector position of the satellites will then be telemetered to ground readout stations.

The telescope will consist of two corrector plates or lenses, a spherical mirror and a detector mosaic. Radiation passes through the first or aspheric corrector plate and then through the second lens with concentric spherical surfaces, finally striking the mirror which focuses the light on the detector mosaic. The mosaic is made up of 56 individual detectors, each consisting of a hemispheric strontium titanate lens onto which a lead sulphide detector cell is immersed. Each lens is 2 mm in diam, with the lead sulphide deposit in the 0.1 mm range.



Cross-sectional view of telescope for satellite surveillance system now under development for AF by Electro-Optical Systems.

NOTHING IS TOO FAR OUT....



This photo characterizes the work Grumman is doing in hypersonic aerodynamics. Other efforts at Grumman include continuing design and development work on orbiting observatories, interplanetary communication systems, re-entry vehicles and reconnaissance satellites, to name a few.

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development of the intermediate-range, air-launched ballistic missile, Skybolt. Assuming reasonable success in the development program, it is felt that this missile system will play an important part in our deterrent capability.

2. The Air Force contracted with two companies for research and development leading to the design and fabrication of large solid-propellant rocket motors capable of producing up to 100 million lb-sec of impulse.

3. NASA contracted with three companies for studies and analyses of the cost effectiveness of solid boosters for large vehicles. The results of the studies will be compared with similar work related to liquid-propellant boosters for large vehicles.

4. The AMERICAN ROCKET SOCIETY sponsored a technical conference for solid rocket specialists at Princeton Univ. in February. It is planned that this top-level technical conference will become an annual event, complementary to the annual JANAF meeting for solid rockets. The next meeting is scheduled for Feb. 1, 2, and 3, 1961, in Salt Lake City.

In conclusion, much has been gained in the past year with respect to understanding the advantages of and increasing the use and usefulness of solid rocket motors. The solid rocket industry has moved a long way down the road to becoming the prime source of low-cost, highly reliable missile propulsion. This future is near.

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Nuclear Propulsion

(CONTINUED FROM PAGE 41)

necessary for the achievement of a nuclear ramjet powered by a reactor instead of a chemical combustor. Of course, basically the ramjet has the merit of being simple. The incorporation of a reactor into the ramjet would add greatly to its usefulness by giving it enormous range.

The development of a nuclear ramjet will undoubtedly involve a normal share of the nuclear and non-nuclear problems. The fact that a ramjet is intrinsically a high-supersonic device creates additional major development problems. One of these problems is to develop fuel-element and structural materials capable of withstanding the high temperatures associated with high Mach-number operation as well as the oxidizing effects of extremely hot air. Another problem stems from the fact that all the system components must be extremely light, despite the severe stress and environmental conditions under which they are to operate. Much progress toward solving these difficult problems has been made during the past year.

The effort of the Pluto project will reach a significant milestone late this fall at the Nevada Test Site, when the first engineering test reactor is scheduled to go critical. It appears that the state of the art is rapidly approaching the stage of hardware development, and that the future looks encouraging indeed.

Rocket Development

The work on nuclear rockets is being carried out under the Rover project at the Los Alamos Scientific Laboratory. The objective of this project is to demonstrate the feasibility of nuclear-rocket propulsion. In a nuclear rocket, a propellant carried aboard the vehicle is simply heated by a reactor and ejected through a nozzle to provide thrust. The problem here is to develop an enormous power in a comparatively light device.

The approach of the Rover project is to conduct a limited number of integral tests with reactors to check out basic material, design, and control problems and then to proceed with more advanced reactors on the basis of this experience. The first of the test devices, Kiwi-A, was carried through its planned operations in 1959 at the Nevada Test Site.

Information obtained from the Kiwi-A test has been incorporated into the design and fabrication of two reactors known as Kiwi-A Prime and Kiwi-A3. These are experimental devices used to checkout design concepts, materials, and operating characteristics of high-temperature, open-cycle, gas-cooled reactors and are not in themselves prototypes of nuclear-rocket engines. Kiwi-A Prime was carried through a planned program of power operation in July 1960, and was then dismantled and examined. The records of the reactor operation and data obtained during the post-mortem examination are used to check on the design calculations and the laboratory tests of components and materials. A similar test of Kiwi-A3 was also conducted.

Work has been started on improved reactors more nearly suited to nuclear-flight applications using higher powers, a propellant-cooled structure, and more rugged control components. Construction of a testing complex for this new family of reactors has been started at the Nevada Test Site. It seems that a continuing effort will result in early development of nuclear rockets suitable for testing in flight.

A special type of nuclear-"rocket" propulsion may result from the use of a series of small nuclear explosions. It appears that the impulse derived from these explosions can be used for propelling space vehicles with large payloads—on the order of 1000 tons. Project Orion deals with research on this concept. Experimental work with high explosives has been pursued. The effort under this project is continuing.

Auxiliary Nuclear Power

Several nuclear-power devices for flight applications are in different stages of advanced development. Some of these, particularly the isotope-powered ones, are designed specifically to provide electricity for communications equipment. Others, such as the complete reactor systems, may provide primary power for low-thrust propulsion as well as auxiliary power. Some of the names which have made news this past year are Snap-3 which uses polonium and produces $3^1/_2$ to 5 watts of power; Snap-1A, which provides 125 watts using cerium-144; and Snap-2, which uses a zirconium hydride-moderated, sodium-cooled reactor providing 3 kw. Development of various power-providing systems is being actively supported.

Nuclear-propulsion techniques, it is clear, are going through an active phase of research and development. In addition, NASA has initiated a study program for the feasibility demonstration of nuclear propulsion through flight testing of nuclear-rocket stages. The Air Force has also initiated studies to generate technical data in the area of nuclear-propulsion systems in anticipation of future needs. A rise of general interest in nuclear propulsion seems to be reflected in the increased funding for programs by the

Federal Government and the increasing number of organizations and individuals participating in various nuclear studies, including the study of gaseous reactors. Indications are that the year 1965 will probably see a test nuclear-rocket stage in flight, and that before the end of the decade we will probably have aircraft and nuclear-rocket vehicles performing useful missions.

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Liquid Rockets

(CONTINUED FROM PAGE 38)

have the benefit of highly efficient, high-performance rocket vehicles (3). This confidence in the future of liquid hydrogen is underlined by NASA's decision to adopt hydrogen as the fuel for all upper stages of the Saturn vehicle. The development of a 200,000-lb thrust upper-stage engine, capable of being clustered, has been initiated for this program (4). Thus early research by government agencies and contractors has brought this important class of device to fruition.

Another technical problem that has concerned vehicle designers has been the ability to start rocket engines during flight at high altitude and in a reliable fashion. Early experience with the Bumper WAC program indicated that difficulties might be expected from this requirement (5). However, our recent experience with the Able program has clearly shown that, with pressurized engines, the problem was capable of solution. Also in the past year, favorable test results with the Agena upper stage, using storable propellants, and with the Titan second stage (6, 7), using cryogenic propellants, have shown that turbopump engines are also able to ignite reliably at high altitude.

An even more impressive achievement of the past year has been the shutdown and subsequent restart capability demonstrated by the liquid rocket. In Ref. 8, an extensive description of the Aerojet Able-Star vehicle is given. This is the unit that has been used twice in boosting Transit navigation satellites into precise orbits, and is the first unit to be restarted after a period of coast. The requirement to restart has also been specified for the pump-driven Agena-B engine of Bell Aircraft and the Centaur engine of Pratt and Whitney. This restart capability is highly desirable to extend the performance and flexibility of space vehicles (9). Engine restart has previously been demonstrated by the engine used in manned experimental rocket aircraft. The Reaction Motors XLR-99 unit now being introduced into the X-15 program has this ability, in addition to having thrust-magnitude control.

Reservations as to the reliability of liquid engines has long been a problem to those charged with the planning of space exploration. It is therefore interesting to examine the record and evaluate the reliability demonstrated to date. If one turns to Ref. 10, where the various space shots, successful and unsuccessful, of the U.S are logged, it will be found that this nation has attempted 22 space launchings in the past calendar year. Of these attempts, 13 have been successful. However, a total of 39 liquid-rocket stages were called upon to ignite during these firings, yet only four times were the liquid rockets responsible for the failure of the mission. Thus the liquid rockets presently in service have demonstrated a reliability of approximately 90 per cent.

Increase Reliability

Certainly engine designers are not satisfied with this performance, and efforts continue to increase the reliability of propulsion systems. One path that has been successfully followed to attain this end is simplification of the engine hardware. For instance, the H-1 engine of Rocketdyne that is used for the Saturn first-stage cluster is a greatly simplified (and up-rated) version of the Thor IRBM engine (11). It may also be expected that reliability will improve in future systems. The movement toward simplification is not yet over by any means. For example, the engine concept advanced by Rocketdyne, where turbine-drive gas is bled directly from the thrust chamber (12), although not fully developed, offers still another path to simplification and increased reliability. Here again, the great, submerged body of research performed over the last five years is starting to show above the surface, and become useful to our needs.

Future ambitious missions in space will require boosters of greatly increased thrust. Two approaches to this requirement have been proposed and are being pursued. One is to cluster a number of smaller thrust chambers, as is being done for the first stage of the Saturn vehicle. The year 1960 has seen the first successful firings of the full Saturn cluster (15). The alternate approach, that of constructing a single engine to deliver a thrust of over 1 million lb, has also achieved its first measure of success in this past year. NASA has announced that the Rocketdyne F-1 engine thrust chamber has been fired for limited durations at a megapound-plus level (16, 17). Indeed, this does not exhaust the inventory of high-thrust devices available to the U.S.A., for an AF-sponsored research program has resulted in successful test firings of a complete 400,000-lb thrust engine (18).

Turning briefly to rocketry for military needs, it has been recognized that quick response and high reliability are of considerable advantage in many applications. It is known, also, that liquid rockets using storable propellants are able to satisfy some of these military requirements and in fact have been used in operational missiles (e.g., Nike-Ajax). Thus small prepackaged liquid-propellant units (13) continue to be developed for use in smaller military missiles. In addition, the virtues of storable propellants for application to large ICBM's has not gone unrecognized. The Air Force has announced that a follow-on version of the Titan missile, using uprated and simplified versions of the present Aerojet engines, will be developed to emphasize reliability and instant readi-

ness, and will employ noncryogenic propellants stored within the missile tanks (14). Here again, the past year has seen advancements following from previous research.

Having now highlighted the past, it rests upon us to examine implications for the future, and to try to point out some areas where present research, if successful, will continue to satisfy our expanding needs. We have seen that it is now possible to count on the performance of hydrogen fuel for upper-stage use, at least. The reliability of turbopump systems is expected to be high enough so that we need not resort to the less-efficient, pressurized booster configurations. The ability to restart engines has been demonstrated, so that staging and navigation techniques can be simplified and improved.

For those missions requiring a soft landing on another body, the ability to modulate thrust is highly desirable, if not absolutely necessary. Again, liquid-rocket technology is showing a considerable measure of success in developing engines whose thrust can be varied as needed (19,20).

While less glamorous than the development of complete engine systems, it is no less necessary to continue with the development of improved components(21). Here the achievements of many agencies and contractors are hidden behind a cloak of anonymity, but are no less real.

Surely rocket technology will not always remain in what is probably the Model-T (or perhaps Model-A) stage. Already more sophisticated and efficient engine design concepts are being created and tested, e.g., plug-nozzle engines (22,23). No doubt engines of the future will little resemble in form the present ungainly configurations.

For completeness, one serious problem, constantly recurring in liquid rocket development, must be mentioned at this time, and that is the problem of scaling combustion chambers and avoiding destructive instability. While other areas of technology have given rocket people a rich background in heat transfer, fluid mechanics, and mechanical design, there is no such well-developed engineering science for high-intensity combustors. To continue to develop ever-larger engines through cut-and-try techniques will incur enormous penalties in the expenditure of money and time. Thus it seems imperative that this problem be attacked by a well-supported and highly coordinated research program.

To conclude, if indeed it be true, as has been claimed by some persons, that the near-term future of astronautics is limited only by the capabilities of rocket vehicles, then the results of the past year show that liquid-rocket-engine technology is rising to the challenge.

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Optimum Program

(CONTINUED FROM PAGE 27)

ical progress is increasing. This should make us stop and ponder. Sure, all these new materials and the new methods and techniques associated with them are bound to have a profound impact on future technology. But should we use them indiscriminately in our space and missile programs, just because it is chic, just because it looks sophisticated, just because one of the other nine competitive bidders may have included them in his proposal? Maybe that good old flex hose wasn't so bad after all.

Any genuine technological progress, and any sophisticated advance, costs plenty of money. Now I am entirely ready to concede that supporting research and development of novel technologies have always fluorished best in the wake of either some moneymaking production venture or some high-priority development project. There is also no doubt in my mind that in the long run our technological civilization will greatly benefit from all those new concepts and methods. But should our missile and space programs, just because they are in the limelight of public interest, always be the pack mule that must carry all that fancy load up the hill?

In the military area (Department of Defense), with our ICBM's and our IRBM's, the very safety and survival of our country is at stake. In the field of scientific and peaceful space exploration (NASA), 80 per cent of the world population sit in the audience while the other 20 per cent, on stage and made up of rocketeers from the U.S. and the U.S.S.R., are trying to convince them as to who is superior in scientific capability of harnessing the forces of nature. My personal feeling is that this worldwide contest is just as serious in the military field as it is in the scientific arena.

What is an optimum missile and space program, then?

I think an optimum program, both in the military missile field and in the area of scientific space exploration, is one which combines the following features:

(1) It must, to a reasonable degree, utilize advanced technical capabilities at the time of its operational availability in order to avoid premature obsolescence.

(2) It must be able to achieve this objective within the existing schedule and funding limitations.

(3) It must, therefore, steer clear of the incorporation of features and techniques which, considering the stringent reliability demands, are beyond the scheduling objectives and the funding limits.

(4) It must be based on the clear understanding that any glib talk about reliability without proper regard to scheduling objectives and funding limitations is meaningless.

(5) It must be based on an understanding of the mentality of our most formidable potential enemy, the Soviet Union.

Maybe Point 5 is the most important of my list. There was a time when Soviet technology was pooh-poohed in this country, when it was predicted that the Russians wouldn't have atomic bombs and jet aircraft for years to come. With the advent of the Sputniks and Luniks this cocksureness was followed by a period of soul-searching and breastbeating, and many people thought we'd never catch up with the Russians. I think it's about time to soberly appraise the other fellow and devise a technological strategy best suited to cope with him. After all, the Soviet Union still has a long way to climb until she will have reached America's—or the Western world's—scientific and technological plateau. But she's coming up fast, frighteningly fast, and we must not fiddle around with nonessentials and thus jeopardize our precarious, elevated position. We must carefully explore what, under the existing circumstances, is an "optimum program" for us.

I think it is quite significant that the Soviets decided to build an ICBM several years before the Pentagon gave the green light to do the same. At that time old Stalin was still running the show. He knew that his next potential enemy was the U.S. and he was well aware of the fact that the Soviet Union didn't have much of a chance to produce a serious challenge to our fabulous Strategic Air Command. So he decided to put his rubles on ICBM's at a time when our own wise men felt that it would be smarter to wait a year or two until nuclear warheads had become lighter and the required carrier ICBM's could be smaller and cheaper. The reasoning on our part was certainly clear and logical at the time—after all, there was still SAC to fall back on in case of trouble—but it gave the Soviets earlier ICBM's and a tremendous advantage in the space exploration field from which we are still trying to recover. Maybe we'd be better off today had we decided to develop a less sophisticated, bigger, ICBM in 1950, rather than an engineer's dream such as the Atlas in 1955. Maybe we optimized too much.

TU-114 Philosophy

When Khrushchev visited the U.S. in 1959, he arrived in Washington in a nonstop flight from Moscow in a TU-114, the largest airliner the world had ever seen. The TU-114 was a turboprop, neither excessively fast nor very economical in operation, but it was the world's largest long-range aircraft nevertheless. I don't have all the facts on the kind of rockets that fired the Sputniks and the Luniks into their respective orbits, but I am pretty sure they were based on the TU-114 design philosophy. And the crux of this philosophy is: "Why spend millions of rubles on weightsaving refinements if nearly the same can be accomplished with a somewhat larger and heavier design? After all, the Americans, and the Western world in general, publish all their scientific and engineering advances in their trade journals anyway. So let's pick up advances made in miniaturization and refinements on the next go-round. In the meantime, let's cash in on what can be reliably built on the status quo."

Maybe you disagree with me that the Russians reason this way. In this case I won't argue with you but let you draw your own conclusions. But if you do agree, I think you will also conclude with me that in our search for any optimum program in the missile and space field we should put the criterion of "*maximum chance of success within the schedule and dollar limitations*" way ahead of all others—ahead of optimum takeoff weight, optimum propellant consumption, optimum use of technological advances, no matter how carefully substantiated—and also way ahead of a company's optimum chances of securing the contract. ♦♦

ARS Annual Meeting Program

(CONTINUED FROM PAGE 57)

Aeronautics and Space Administration Washington, D.C.

- ✦Thermoelectricity, Paul Egli, Naval Research Laboratory, Washington, D.C.
- ✦Thermionics, Wayne Nottingham, Massachusetts Institute to Technology, Cambridge, Mass.
- ✦Solar Cells, Paul Rappaport, Radio Corporation of America, Princeton, N.J.
- ✦Galvanic and Fuel Cell Batteries, Arthur Daniel, U.S. Army Signal Research and Development Laboratory, Fort Monmouth N.J.
- ✦Advanced Mechanical Conversion, Walter K. Deacon, Vicker, Inc., Torrance, Calif.
- ✦Solar Systems, Nathan W. Snyder, Institute for Defense Analyses, Washington, D.C.
- ✦Nuclear Space Power Systems, G. M. Anderson, Atomic Energy Commission, Washington, D.C.

STRUCTURES AND MATERIALS

9:00 a.m. **Terrace Banquet Room**

Chairman: Edward A. Simkovich, Republic Aviation Corp., Farmingdale, N.Y.

- ✦Composite Thermal Protection Systems for Manned Re-Entry Vehicles, Robert T. Swann, National Aeronautics and Space Administration, Langley Field, Va. (1569-60)
- ✦Advanced Materials and Techniques for Space Applications, F. J. Stimler, Goodyear Aircraft Corp., Akron, Ohio. (1570-60)
- ✦Reinforced Carbonaceous Material Systems, B. A. Forcht and M. J. Rudnick, Vought Astronautics, Div. of Chance Vought Aircraft, Inc., Dallas, Tex. (1571-60)
- ✦Composite Ceramic-Metal Systems for 3000-6000 F Service, S. R. Locke, H. Leggett and A. V. Levy, Hughes Tool Co., Culver City, Calif. (1572-60)
- ✦Development of Ultra-High Temperature Tungsten-Base Composites for Rocket Nozzle Applications, Samuel R. Maloof, Avco Research and Development Div., Wilmington, Mass. (1573-60)

MISSILES AND SPACE VEHICLES

2:30 p.m. **Main Ballroom**

(Papers to be Announced)

STRUCTURES AND MATERIALS

2:30 p.m. **Terrace Banquet Room**

Chairman: Edward A. Simkovich, Republic Aviation Corp., Farmingdale, N.Y.

- ✦Prospects for Reinforced Plastics in Structures, I. J. Gruntfest and Norris F. Dow, Missile and Space Vehicle Dept., General Electric Co., Philadelphia. Pa. (1579-60)
- ✦A Numerical Analysis for the Determination of Stresses and Displacements in a Multi-Layer and Multi-Sectional Shell of Revolution, P. P. Radowski, M. R. Bolduc, and R. M. Davis, Avco Research and Development Div., Wilmington, Mass. (1580-60)
- ✦The Effect of Resin Systems on the Strengths of Filament Wound Fiberglass Composites, R. M. Kyte and D. Pollmann, Aero-Space Div., Boeing Airplane Co., Seattle, Wash. (1581-60)
- ✦A Composite Material Approach to an Efficient Pressure Vessel, J. W. Farrell, Temco Aircraft Corp., Dallas, Tex. (1582-60)
- ✦The Effect of Glass Fiber Geometry on Composite Material Strength, J. Bell, Aero-Space Div., Boeing Airplane Co., Seattle, Wash. (1583-60)

UNDERWATER PROPULSION

2:30 p.m. **West Ballroom**

Chairman: Herman E. Sheets, Electric Boat Div., General Dynamics Corp., Groton, Conn.

Vice-Chairman: George F. Wislicenus, Ordnance Research Laboratory, Pennsylvania State University, University Park, Pa.

- ✦Magnetohydrodynamics: Equations, Parameters and Bibliography, Robert B. Banks, Northwestern University, Evanston, Ill. (1584-60)
- ✦Introduction to Free Jets Exhausting from Supersonic Nozzles into a Liquid Environment, Conrad R. Huskey, Elkton Div., Thiokol Chemical Corp., Elkton, Md. (1585-60)
- ✦Lithium and Sodium as Water-Reactive Fuels for Underwater Propulsion, William D. White, U.S. Naval Ordnance Test Station, Pasadena, Calif. (1586-60) ♦♦

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